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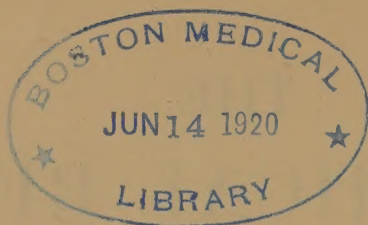
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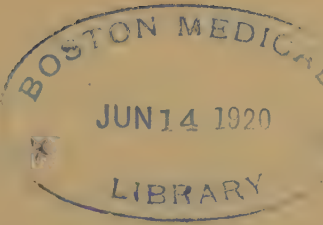
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Resumen por el autor, Frank Blair Hanson.
Universidad Washington, Saint Louis.

El desarrollo de la cintura escapular de *Sus scrofa*.

En el cerdo la cintura escapular está reducida a su mas mínima expresión, consistiendo simplemente de dos piezas, la escápula y el subcoracoides. Las clavículas, acromion y el proceso coracoides están completamente reducidos. La cintura escapular de este animal es además una estructura primitiva que lleva una supra-escápula de gran tamaño y estructura cartilaginosa permanente. La escápula probablemente no es una estructura segmentaria y el subcoracoides puede ser simplemente una epífisis.

Translation by José F. Nonidez
Carnegie Institution of Washington



THE DEVELOPMENT OF THE SHOULDER-GIRDLE OF SUS SCROFA

FRANK BLAIR HANSON

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SEVEN PLATES (TWENTY-EIGHT FIGURES)

INTRODUCTION

It was the idea of Mall, and also of His, that an embryological study should be carried to its logical conclusion, i.e., followed on through the stages of organogenesis and to adult life. Development is a life-long process, and an investigation can only approximate completeness which takes into account this fact. This paper in a most modest way is an attempted illustration of this principle.

In order to compress the material as compactly as possible, the body of the article contains only a discussion of the more general features of the pig scapula, while the anatomical details of each stage are briefly stated in the explanation of figures 1 to 28.

One of the admitted difficulties of following an embryological investigation into fetal and postnatal life is often the scarcity or inaccessibility of the material. In this present instance I am greatly indebted to Mr. A. J. Green, superintendent of the Swift Packing Company plant in St. Louis, for the series of fetal and postnatal scapulae used in this investigation. The drawings were made by Miss Bertha Uhlemeyer, whose aid makes possible the appearance of the paper at this time.

GENERAL DISCUSSION

There is neither an account nor figures of the pig scapula to be found in the literature, so far as I am aware. Yet in several respects this bone is unique among mammalian scapulae. In the pig the shoulder-girdle is reduced to its lowest terms, con-

sisting simply of two pieces, the scapula and the subcoracoid, glenoid sharing element. Clavicles, acromian, and coracoid process are completely aborted, indicating the maximum amount of degeneration possible with continued functional efficiency. The loss of the clavicles is naturally followed by the disappearance of the acromian, except as it may occur in a rudimentary nodule of bone at the lower end of the spine (fig. 23).

The disappearance of the coracoid process may be accounted for as follows: Broom ('97, '98, '99, '02) found that in all groups of marsupials the embryos and fetuses had a coracoidal bar extending from the acromial process of the scapula to the anterolateral margin of the sternum. As development proceeds, degeneration sets in at the middle of this coracoidal bar and, proceeding in each direction, causes the complete disappearance of the sternal half of the coracoid. In the scapular half of the coracoid degeneration is incomplete, leaving attached to the scapula the well-known coracoid process of the adult marsupial. It is highly probable that this is the explanation of the presence of the coracoid process in all groups of mammals. Paterson ('00, '02, '04) found in the rat a mesenchymatous coracoidal bar extending from the mesenchymatous anlage of the scapula to the fundament of the presternum. Here also degeneration in an early stage removes this coracoid, but, unlike the marsupial, not only is a coracoid process left attached to the scapula, but the sternal half is represented here also by a coracoid process attached to the sternum. This persists into adult life as a little nodule of bone lying between the clavicle and first rib, and is called by Parker ('68) the epicoracoid.

In the pig a third variation of this process is illustrated, for here the degeneration is complete in both the sternal and scapular halves of the coracoid, leaving no trace of its embryonic existence either on sternum or scapula. I have verified Paterson's account of the presence of a complete mesenchymatous coracoid in the rat, mouse, cat, and human embryos. Watson ('17) has checked up Broom's work on the marsupials. It is, therefore, well established for a few representative mammals, and is probably true for all, that such an embryonic coracoid does occur,

the only evidence of its existence in the adult being the well-known and much-discussed coracoid process.

The subcoracoid (fig. 27), which in the pig occupies roughly one-third of the area of the glenoid surface, I have discussed elsewhere (Hanson, '19). Suffice to say here that its homologies are still in uncertainty; it may be merely an epiphysis such as occurs on long bones, as suggested by Broom and Gregory ('18). The subcoracoid is ossified from a separate center which does not appear until some months after birth. There is but one other center of ossification in the shoulder-girdle of the pig, that of the blade part of the scapula.

Not only is the scapula highly degenerate, but it also shows an unmistakable primitiveness in the possession of a large and permanent suprascapula. By reference to the figures it will be seen that in the oldest scapulae the suprascapula retains the same relative proportions to the scapula as in the fetal scapulae. There is no evidence of even the beginning of ossification in the scapula of a boar (fig. 28) which weighed 450 pounds and was evidently of considerable age. In most mammals advancing age brings an ossification and reduction in size of the embryonic suprascapula, to which rule the pig appears to be an exception. I have shown (Hanson, '18) that in a phylogenetic ascending series of mammalian scapulae the progressive diminution of the suprascapulae follows closely the steps of ontogenetic development in the highest order of mammals. The permanent suprascapula of the pig recalls conditions in the Amphibia and Reptilia.

The pig has a scapular index ranging from 137 to 150, these measurements, however, are based on only a dozen blade bones. The scapular index of any animal is obtained by multiplying the length from the glenoid to the vertebral border by 100, and dividing this by the distance from the medial to the inferior angle. It is interesting in this connection to note that the cat has a scapular index of 200, while that of man averages only 65 for the white races.

Kingsley ('00) has suggested that the presence of nerves and their foramina in the suprascapula might possibly indicate that the scapula was made up of metameric parts. Bolk's studies of

the muscles of the shoulder-girdle, together with the fact that when the suprascapula ossifies, as in man, it is by a series of ossific centers, which might indicate previously existing, separate, metameric bones, lend support to this theory, as does also the generally constant division of the scapula in mammals into a prescapula, mesoscapula, and postscapula. However, since the presence of the nerves in the suprascapula is merely a secondary association, as shown by Hanson ('19 b), and, further, when it is considered that the mammalian scapula is the undoubted homologue of the cartilaginous scapula of the dogfish, which is a simple bar of cartilage, that could in no way possible be related to metamerism, it seems impossible to accept the theory of a metameric origin for the scapula.

Attention is called to figures 14, 15, 24, and 25, which are of wild pigs from Honduras, the Celebes, and Borneo. The scapulae are essentially like those of *Sus scrofa*, but are much narrower and stand higher on the animal's body than in the domestic pig. Nerve foramina are present, while acromian and coracoid process are lacking.

As will be seen by the figures, the suprascapula, both fetal and adult, contains a varying number of nerve foramina. Hanson ('19 b) has given an account of this peculiarity, and believes it to be limited to the family Suidae among living mammals. Since the publication of my paper on this subject, Dr. R. L. Moodie has called my attention to a fossil scapula of *Trachodon annectens* containing what might be interpreted as a nerve foramen. This scapula is described by Beecher¹ as follows:

The right scapula is well preserved and shows one very interesting feature. Near the lower edge of the blade is an elongate elliptical hole, 8 cm. in length, with smooth edges, indicating that the animal received a severe injury during life and completely recovered from it before death. It is, of course, idle to speculate on the character of this accident, yet the presence in the same beds of numerous remains of the armored and horned *Triceratops* suggest that there may have been an encounter between this *Claosaurus* and one of the individuals of the *Ceratopsidae*. The injury to the scapula is just such a one as could be made by a thrust of one of the horns of *Triceratops*.

¹ Trans. Conn. Acad. Arts and Sc., 1902, vol. 11, p. 322, pl. 44, fig. 1.

Thus Beecher regards this opening as pathologic or merely the result of an accident. Moodie,² on the other hand, feels sure that Beecher is mistaken, and that we are here dealing with the nerve foramina of possibly aberrant spinal nerves. This latter contention is further corroborated by the presence of similar bony foramina in some of the dinosaurs, branchiosaurs, and cotylosaurs.

It is a matter of regret that at the present time the collection of fossils containing the *Trachodon* scapula is in storage and not available for reexamination.

CONCLUSIONS

From the foregoing account of the pig scapula, the following facts seem pertinent:

1. There is a permanent suprascapula, in which no centers of ossification ever appear.
2. There are in the entire shoulder-girdle only two ossific centers: one for the scapular blade and one for the subcoracoid.
3. Coracoid process, acromian, and clavicle are aborted.
4. The scapula is both primitive and degenerate.
5. The scapula is probably not a segmental structure.

² From a private communication to the author dated March 8, 1919.

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PLATES

ABBREVIATIONS

Ac, acromian
Cr, coracoid
Gl, glenoid
Nf, nerve foramina

Sc, scapula
Sp, spine
SSc, suprascapula

PLATE 1

EXPLANATION OF FIGURES

- 1 Left scapula, 26-mm. embryo. Entirely cartilaginous. $\times 8$.
- 2 Right scapula of 33-mm. embryo. Center for ossification of blade has appeared, and occurs as a band of young bone cells occupying the upper part of the lower third of the scapula. $\times 7$.
- 3 Right scapula of 37-mm. pig, showing growth of bony part. Spine outlined in the cartilage and nerve foramina are present in the suprascapula. $\times 5$.
- 4 Left scapula of 47-mm. pig. $\times 5$.
- 5 Right blade bone of 72-mm. pig. $\times 4$.
- 6 Right blade bone of 77-mm. pig. Limits of future suprascapula outlined. Subcoracoid remains cartilaginous until after birth. $\times 4$.
- 7 Right scapula of 95-mm. pig. $\times 4$.
- 8 Right scapula of 107-mm. pig. $\times 3$.

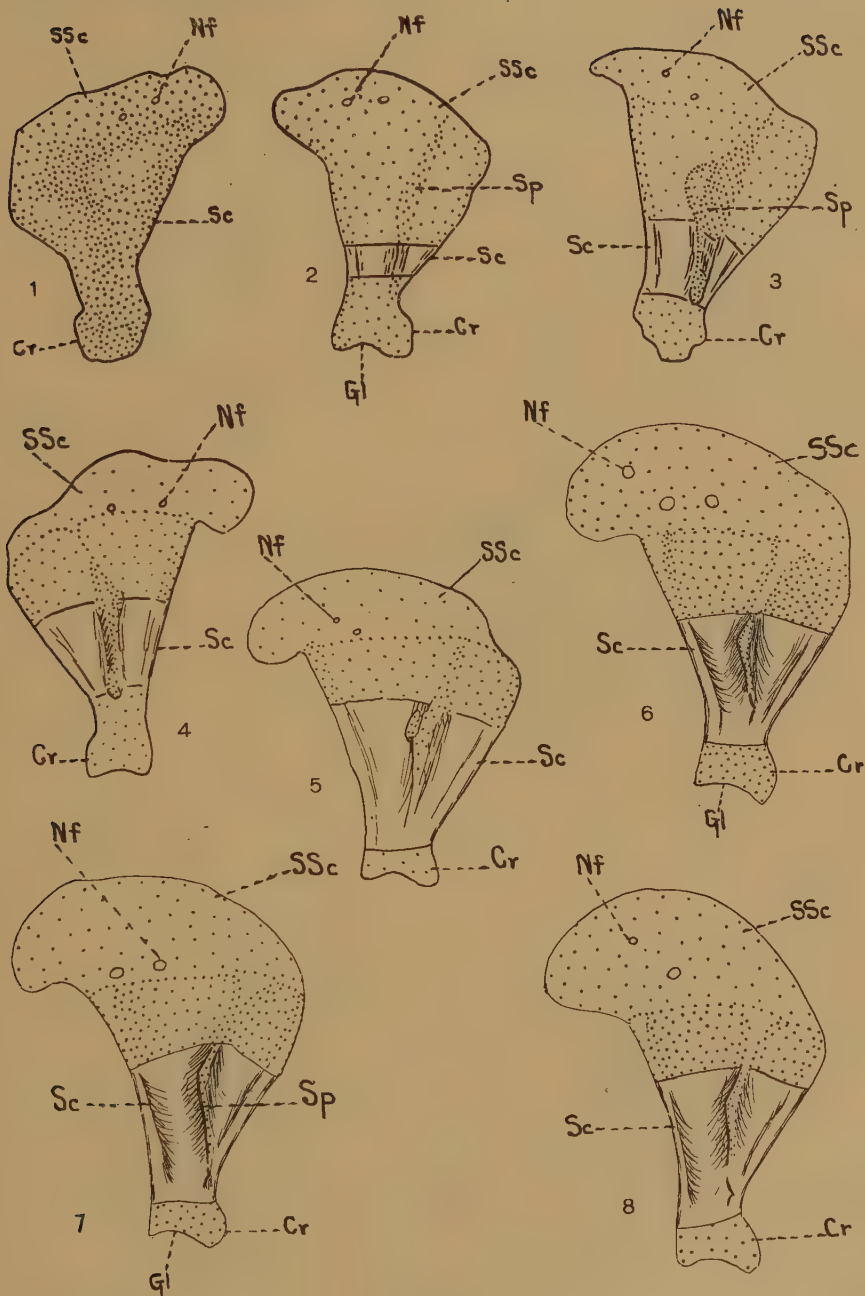


PLATE 2

EXPLANATION OF FIGURES

- 9 Right scapula of 131-mm. pig. $\times 2$.
- 10 Right scapula of 137-mm. pig. $\times 2$.
- 11 Right scapula of 150-mm. pig. $\times 1$.
- 12 Right scapula of 177-mm. pig. $\times 1$.
- 13 Right scapula of 200-mm. pig. $\times 1$.

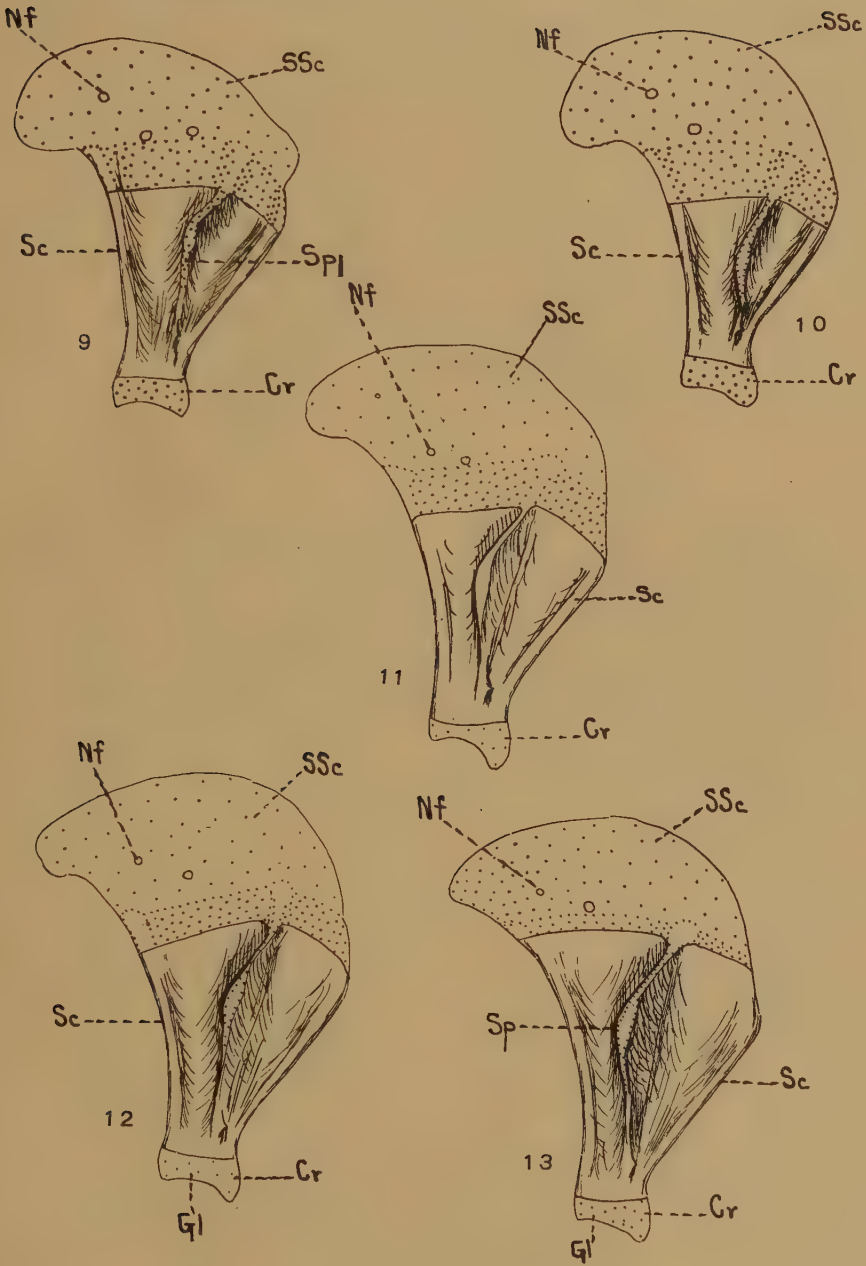


PLATE 3

EXPLANATION OF FIGURES

14 Right scapula of *Sus barbatus* fetus from Borneo. U. S. Nat. Mus. specimen, no. 5751. Bony scapula has now reached limits of its development, and is capped by what will be the permanent suprascapula.

15 Left scapula of *Tayassu* fetus from Honduras. U. S. Nat. Mus. specimen, no. 10214. Is peculiar in having only one nerve foramen.

16 and 17 Full term feti of domestic pig. Medial and lateral views. Adult shape of scapula has now been assumed.

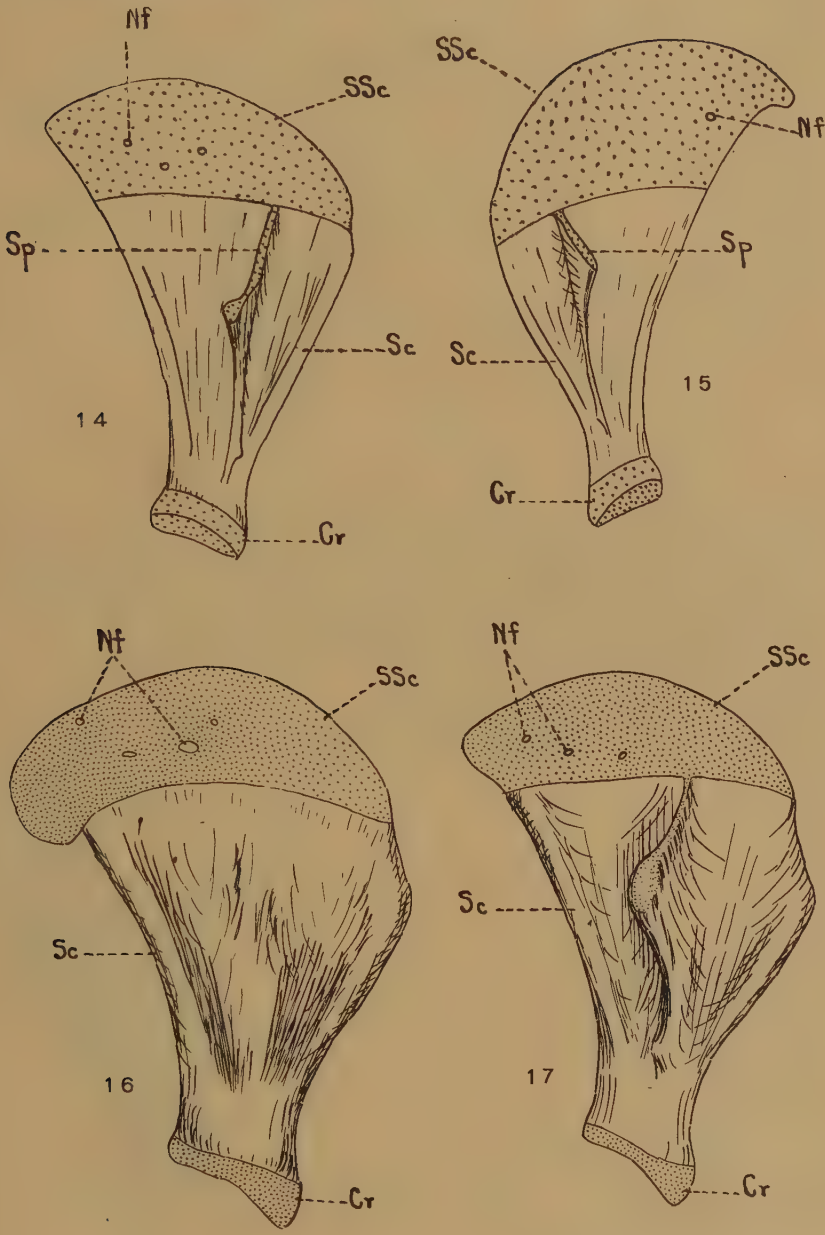


PLATE 4

EXPLANATION OF FIGURES

18 Lateral view of scapula of pig two weeks old. (1) length of scapula from glenoid to suprascapular border 50 mm.; (2) length of bony scapula 40 mm.; (3) width of suprascapula 10 mm.; (4) width of scapula through highest part of spine 23 mm.; (5) height of spine 6 mm. Note: Measurements of remaining scapulae will be given in same order as above and in millimeters.

19 Medial view of scapula of pig three weeks old. Measurements, 45x37x8x13x8.

20 and 21 Lateral and medial views of pig approximately three months old. Measurements, 120x98x22x60x20. Coracoid is still cartilaginous.

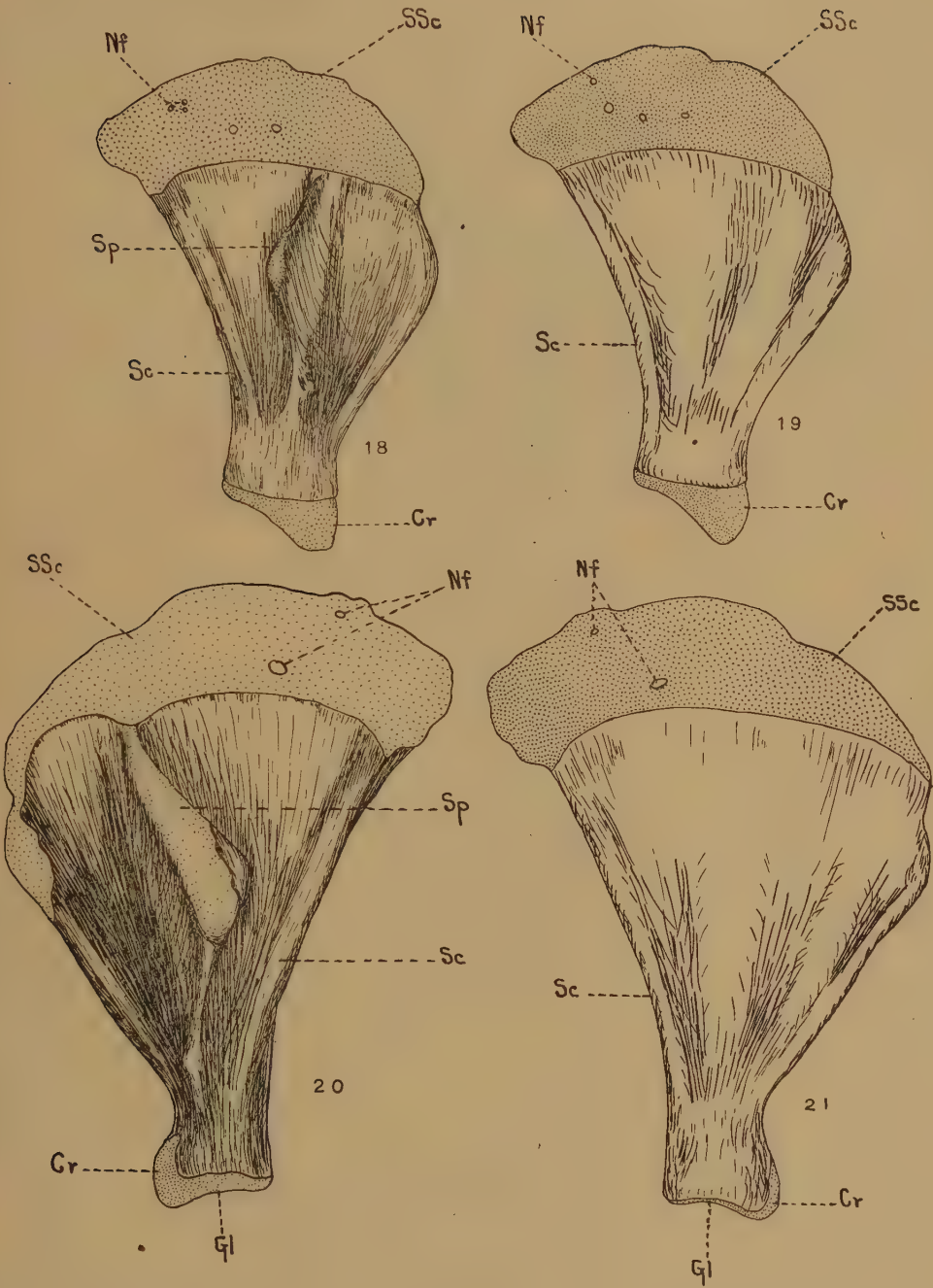


PLATE 5

EXPLANATION OF FIGURES

22 Medial surface of half-grown or six months pig. Only two nerve foramina are present. Measurements, 160x132x25x70x30.

23 Lateral surface of animal approximately nine months of age. Highest point of spine remains permanently cartilaginous. Rudimentary acromian is present. Considerable cartilage still found in the subcoracoid. Measurements, 195x155x40x105x35.

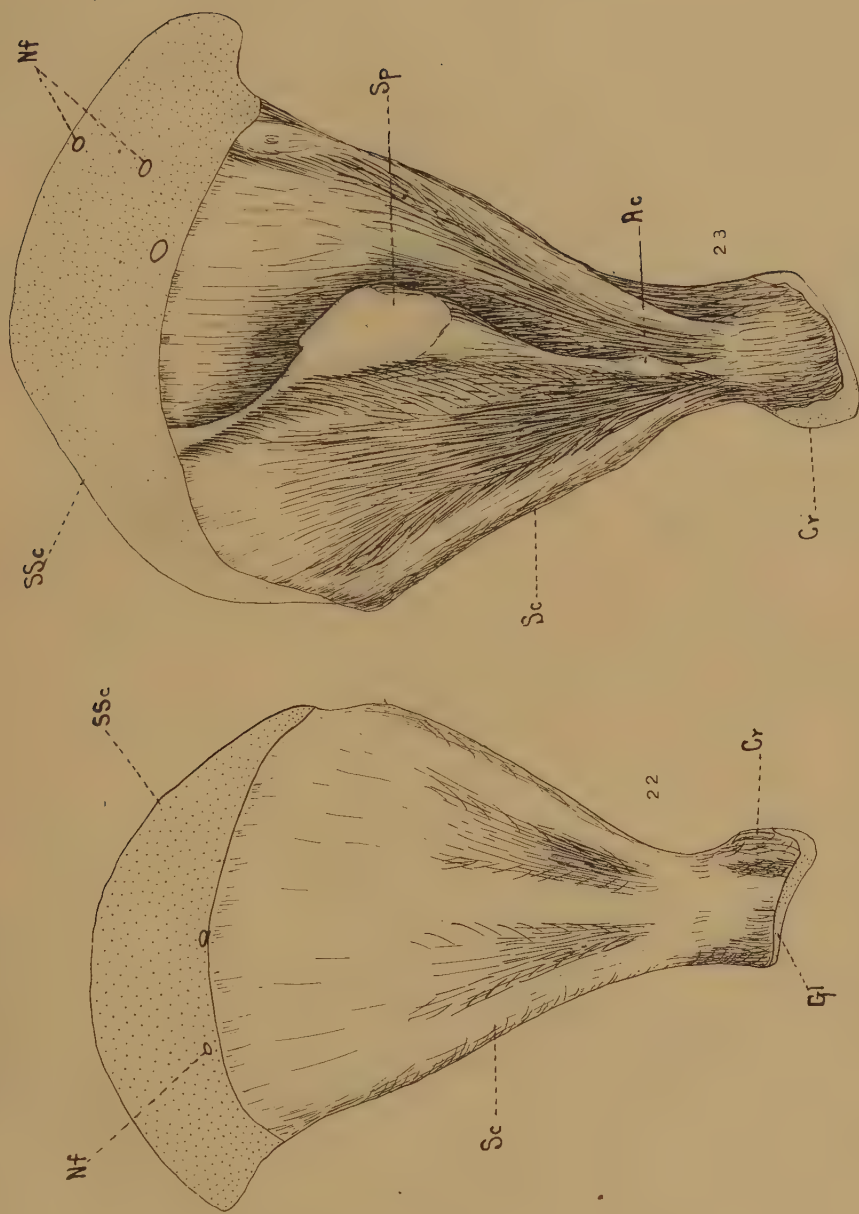


PLATE 6

EXPLANATION OF FIGURES

- 24 Scapula of Babirussa from the Celebes. U. S. Nat. Mus. specimen, no. 199891. Measurements not taken. Adult animal.
- 25 Scapula of *Sus barbatulus* from West Borneo. U. S. Nat. Mus. specimen, no. 145292. Measurements not taken. Adult animal.

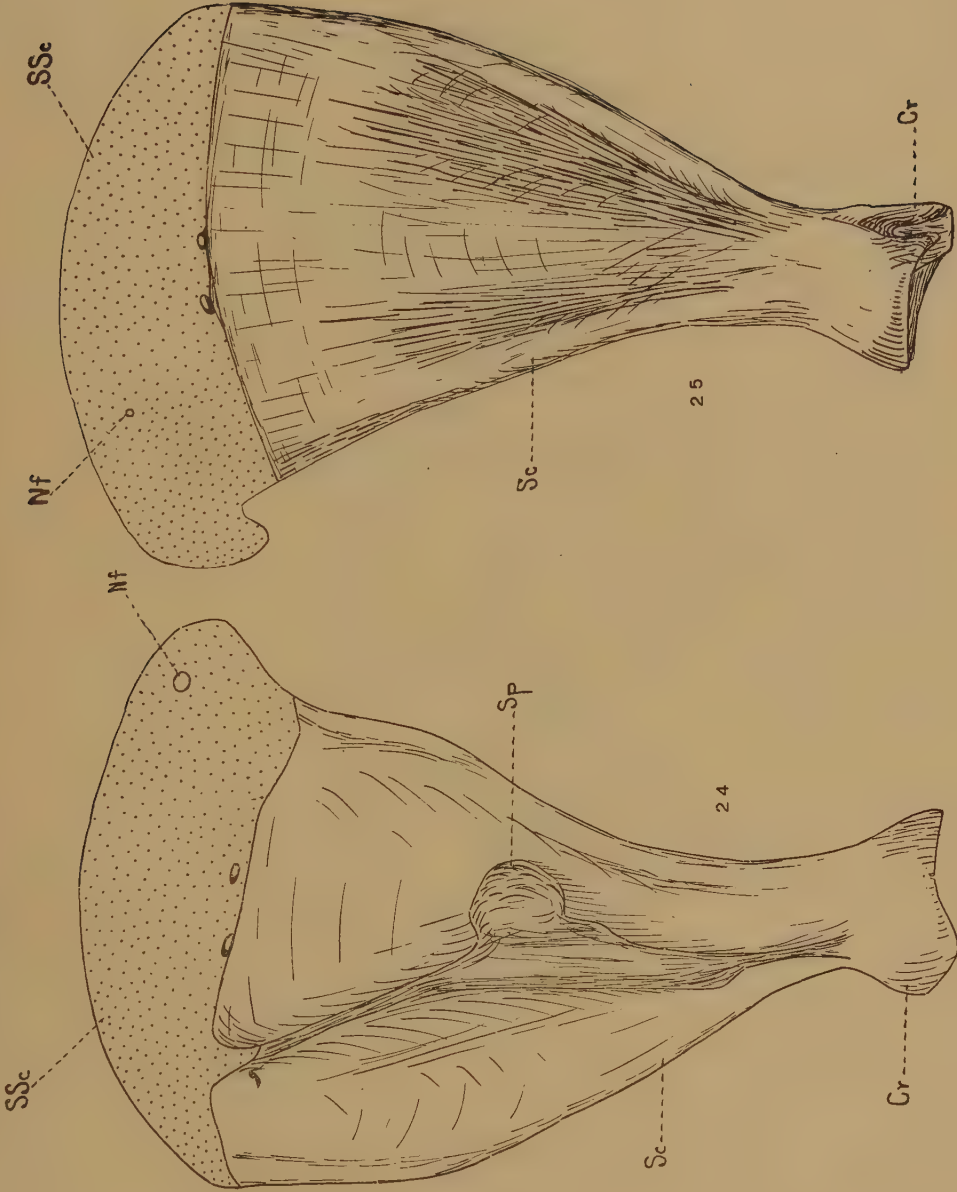


PLATE 7

EXPLANATION OF FIGURES

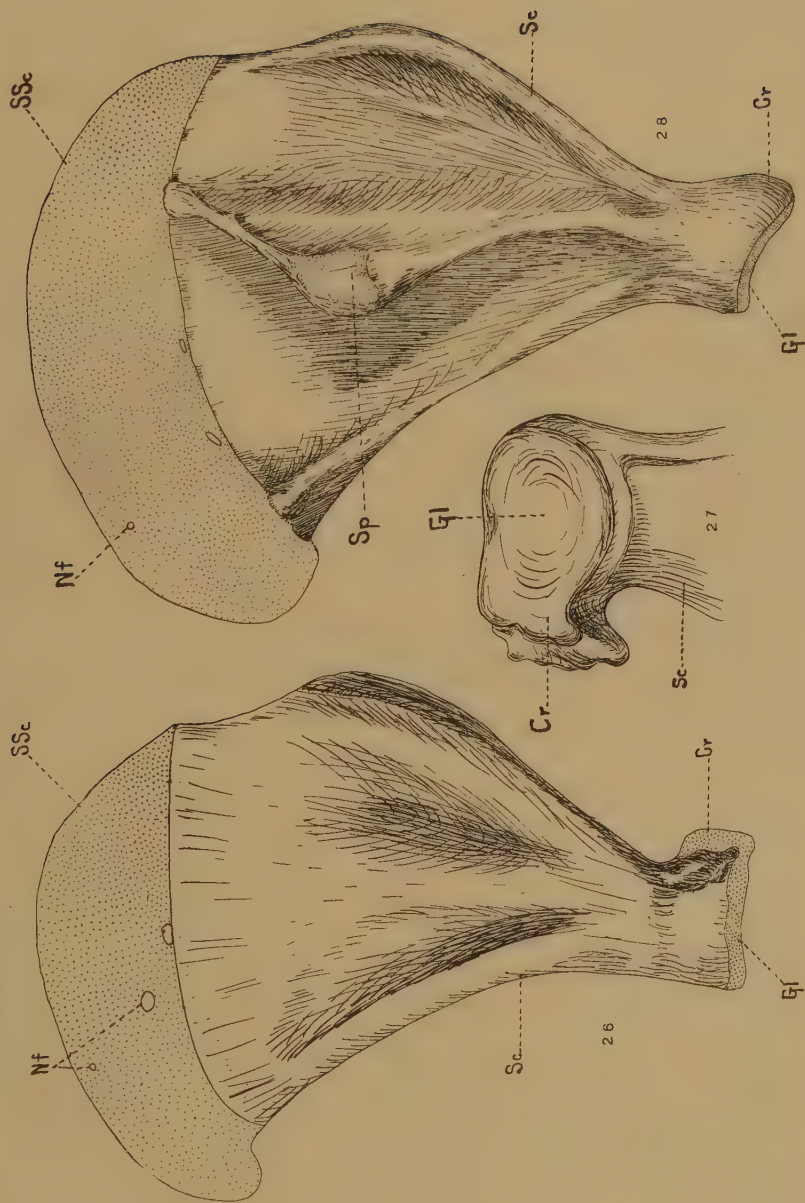
26 Pig one year old or young adult. Weight, 250 pounds. Two spinal nerves, one of them with a small branch, pass through suprascapula. Subcoracoid has small layer of cartilage on outside, but large bony center. Measurements, 230x190x40x125x40.

27 Glenoid and subcoracoid of adult scapula. Coracoid completely fused with glenoid.

28 Lateral surface of scapula of old boar (age unknown). Weight, 450 pounds. Note large amount of cartilage in glenoid, spine, and suprascapula (stippled areas). Measurements, 260x210x50x135x45.

THE SHOULDER-GIRDLE OF *SUS SCROFA*
FRANK BLAIR HANSON

PLATE 7



Resumen por el autor, J. A. Badertscher.
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Leucocitos eosinófilos en el timo del cerdo después del nacimiento.

El autor obtuvo el material usado en esta investigación en una cría de seis cerdos y en dos cerdos jóvenes de 7 meses de edad. Los cerdos de la cría fueron sacrificados, uno a las pocas horas después del nacimiento, los otros a los 7 días y medio, 15 días, 28, 42 y 56 días, respectivamente. Los leucocitos eosinófilos abundan mas en el timo de algunos cerdos que en el de otros. Aparecen aislados o en grupos, tanto en los lóbulos del timo como en el tejido conjuntivo interlobular. Su número varía en los diferentes lóbulos presentes en un mismo corte. Los que aparecen aislados en el interior de los lóbulos están esparcidos de un modo uniforme por la corteza, aunque sin formar capas espesas, mientras que en la médula abundan mas cerca del límite entre la corteza y médula, que en su porción mas central. En los lóbulos del timo los grupos de leucocitos eosinófilos están casi enteramente confinados a la médula. En los cortes de los lóbulos la médula contiene mas leucocitos eosinófilos que una misma extensión de área cortical. Los leucocitos eosinófilos en todos los estados del desarrollo existen en todas las glándulas timo empleadas en la presente investigación. Son de tamaño variable y en su mayor parte poseen un núcleo redondo o casi redondo. En algunos el núcleo es lobulado. Pueden observarse todos los estados de transición del núcleo redondo al lobular. La estructura de ambas clases de núcleos en estas células es la misma que la de los núcleos de los linfocitos. Algunos leucocitos eosinófilos se dividen, pero la mayor parte se forman directamente a expensas de los linfocitos del timo. La formación de los leucocitos eosinófilos en el timo del cerdo después del nacimiento sugiere la existencia de una función hematogénica que no se ha atribuido generalmente a dicho órgano.

EOSINOPHILIC LEUCOCYTES IN THE THYMUS OF POSTNATAL PIGS

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The presence of eosinophilic leucocytes in both the developing and postnatal thymus of mammals is knowledge common to anatomists. However, in the large amount of investigative work that has been done on the histogenesis, structure, and function of the thymus, these cells have, in general, received only a comparatively slight consideration as to their origin. Some investigators have merely recorded their presence in the thymus, while some have given special attention to these cells. A few of the latter group of investigators have, I believe, correctly traced their origin, noted the similarity in structure of many of these cells to the eosinophilic myelocytes in bone-marrow, and yet the view that the thymus is a possible source of polymorphonuclear eosinophilic leucocytes found in the peripheral blood stream is a function not generally attributed to this organ. Neutrophilic and basophilic cells in the thymus have received but little attention and references in the literature to their presence in this organ are only few in number. In this investigation special attention was directed to the eosinophilic leucocytes.

Schaffer ('91) was apparently the first investigator¹ to call attention to eosinophilic cells in the thymus. In various developmental stages of the human thymus he found large numbers of these cells in the connective tissue surrounding the thymus, in the interlobular connective tissue septa, and along the course of some of the capillaries in the medulla. Only a few were found in the cortex. Their nuclei he described as being round. In the

¹ From the nature of the fixer and stain used by Watney ('78), it is not clear whether or not the numerous granular cells he found in the thymus (birds, reptiles, mammals) were eosinophilic cells. The granular cells he derived from connective tissue cells.

same year V. Braunschweig² found them in the thymus of the rat. In the thymus of rabbit and cat Schaffer ('93) found red blood-cells in various stages of development, and transition forms between the leucocytes and nucleated red blood-cells. He believes that the thymus has an hematopoietic function. Again in 1909 Schaffer (Schaffer and Rabl) found many eosinophilic cells and numerous free eosinophilic granules in the medulla of the involuting thymus of the mouse. He derived the eosinophilic cells from the usual thymic cells "durch Aufnahme eosinophiler Körnchen." Concerning their function he believes, "dass sie mit der Fortschaffung epithelialer Zerfallsprodukt in Zusammenhang stehen."

Maximow ('09) found in the thymus of embryo rats eosinophilic cells with round nuclei. These he called eosinophilic myelocytes and believes they are derived from the 'primitive leucocytes.'

Barbano ('12) found eosinophilic cells in the human thymus (normal, involuting, pathological) that were variable in size and most of them contained a round nucleus. He regarded them as differentiated thymic cells.

Ghika ('01)³ examined the thymus of a four-weeks-old and a five-months-old human embryo. He found eosinophilic cells in the cortex, particularly in relation with blood vessels, and in the interlobular connective tissue septa. He also found them in the thymus of full-grown rats. Also, considering the fact that in some infections these cells increase enormously in number, he believes that the thymus may take on an hematopoietic function.

Schridde ('11) believes that the eosinophilic cells found in the human thymus are 'typical leucocytes.' All had a lobed nucleus. He therefore thinks that they have migrated into the thymus from the blood.

Badertscher ('15) found that eosinophilic cells are present in the thymus in quite early developmental stages of pig embryos. They increase in number with the development of the embryo so that in late developmental stages they are most numerous.

² Reference cited from Weill ('13).

³ Reference cited from Weill ('13).

They are found in both cortex and medulla and in the interlobular connective tissue septa. Most of them have a round or nearly round nucleus, while some have a polymorphic nucleus. All gradations between the round and lobed nuclei can be found. They are derived from the large and medium-sized lymphocytes.

Weill ('13) examined the thymus of full-grown rats and four men (15, 17, 19, and 37 years old). He found that in the thymus of both rat and man the eosinophilic cells have a similar distribution, being more numerous in the cortex and interlobular connective tissue septa than in the medulla. The form of the nucleus varies from round (mononuclear) to many lobed in man, and from round to ring shape in rat. Those with a round nucleus are most numerous, but all gradations between round and many-lobed and ring-shaped nuclei can be found. In the thymus of both rat and man the granules are numerous in these cells, and are distributed throughout the cytoplasm of the cell, excepting in some cells there is a small area near the nucleus free from granules. The mononuclear eosinophilic cells are identical in structure with the eosinophilic myelocytes in the bone marrow. Some were found in mitotic division. More of these cells were found in mitotic division in the thymus of the rat than in the thymus of man. These cells have an autochthonous origin, some being derived directly from the thymic cells by the formation of granules in them, while others arise through division of eosinophilic cells. Through the transformation of their nucleus they become identical in structure with the eosinophilic leucocytes in the blood.

The material used for this investigation was obtained from a litter of well-nourished pigs and from two well-nourished young adult hogs seven months old. The pigs were killed at the following ages: One a few hours after birth, one 7.5 days old, one 15 days old, one 28 days old, one 42 days old, and one 56 days old. Small pieces of various segments of the thymus (thymus head, cervical and thoracic segments) were fixed in Zenker-formol solution and embedded in paraffin and collodion.⁴ A portion of

⁴ A comparison of stained sections obtained from each of two pieces of the collodion and paraffin embedded material showed that no appreciable difference could be detected between the quality of the material. The material embedded in paraffin was therefore exclusively used.

each segment of the thymus was cut in sections 3. to 5 μ in thickness. The sections were mounted in serial order and stained with azur II eosin and Hastings-Nocht's stain. Smear preparations were also made of ground pieces of fresh thymus of the young adult hogs to check on the neutrophilic cells. These, as well as smear preparations of blood and bone marrow of the young adult hogs, were stained with Wright's and Hastings-Nocht's blood stain. Portions of the thymus were also fixed in absolute alcohol for the preservation of cells containing basophilic granules.

Eosinophilic leucocytes in all stages of development are present in the thymus glands of all the pigs and adult hogs. Although these cells vary somewhat in number in the thymus of the different pigs, the manner in which they are distributed is, in general, the same. It is, therefore, not necessary to give a detailed consideration of these cells as they occur in each thymus.

Eosinophilic leucocytes are present in both the thymic lobules and in the interlobular connective tissue, in both regions of which they lie singly and in groups. They vary in number in the different lobules present in a single section of the thymus. Those lying singly inside the lobules are thinly but quite uniformly scattered throughout the cortex, while in the medulla they are usually more numerous near the boundary line between the cortex and medulla than in its more central portion, although occasional lobules are found in which the distribution of eosinophilic leucocytes lying singly are quite uniformly scattered throughout the medulla. The groups of eosinophilic leucocytes are usually found in connection with small blood-vessels which they may entirely surround, or may lie on one side of them, or they may be promiscuously scattered along their course. An occasional group may be found in connection with a thymic corpuscle, while some groups apparently lie independent of either blood-vessel or thymic corpuscle. The number of eosinophilic leucocytes in a transverse section of a single group may vary from a few to as many as two hundred. The number may be much greater if a long group along the course of a blood-vessel is cut in a longitudinal direction. Some groups are composed entirely of eosino-

philic leucocytes, while in some groups they are interspersed with lymphocytes (thymic cells). Groups of eosinophilic leucocytes are almost entirely confined to the medulla. Only an occasional group is found in the cortex, and these are present chiefly in the connective tissue trabeculae extending into the cortical region from the connective tissue surrounding the lobules. Only very seldom is a group found directly in the cortical parenchyma.

In sections of lobules of the thymus of all the pigs and young adult hogs examined the medulla contains more eosinophilic leucocytes than does a cortical area of equal extent. The distribution of these cells in the lobules apparently differs in different animals, for Weill ('13) found that in the thymus of rat and man they are much more numerous in the cortex than in the medulla.

The eosinophilic leucocytes are more numerous in the thymus of some pigs than in others. The order of arrangement of the pigs as to the number of eosinophilic leucocytes in the thymus, beginning with the one in which they are least numerous, is as follows: Pig 14 days old, pig 7.5 days old, pig at birth and pig 28 days old about equal in their distribution, pig 56 days old and young adult hogs about equal in their distribution, and pig 42 days old. A general idea of their number in the pigs 14 and 42 days old may be obtained thus: In most of the microscopic fields (Zeiss 1.8 mm., N.A. 1.3, oil-immersion objective, and X8 ocular) in the medulla of the thymus in the pig 14 days old are found from three to eight eosinophilic leucocytes, although on occasional field with twelve, thirteen or fourteen cells and an occasional one with none can be found. In the cortex, microscopic fields containing from one to three eosinophilic leucocytes are quite readily found, while an occasional field with five cells may be found. Fields containing none can readily be found. In most of the microscopic fields (same magnification as above) in the medulla of the thymus in the pig 42 days old are found from seven to about twenty eosinophilic leucocytes, while an occasional field containing from thirty to thirty-six cells is found. In the cortex the majority of fields contain from four to about eight cells, while in an occasional field as many as fourteen may be

found. Fields with no eosinophilic leucocytes in them can only seldom be found in both cortex and medulla. As stated above, some of the lobules in a thymus contain a larger number of eosinophilic leucocytes than others. The counts given above were made from lobules that contain about an average number of these cells. Groups of eosinophilic leucocytes are also more numerous in the thymus glands that contain a relatively large number of these cells lying singly.

In the interlobular connective tissue septa the eosinophilic leucocytes are usually most numerous in those places where the connective tissue is loosely arranged. Some may, however, be found in the more dense connective tissue between lobules crowded closely together. Most of them are found in relation with small blood vessels. They are most numerous in the interlobular connective tissue of the thymus in those pigs in which these cells are greatest in number in the lobules.

The eosinophilic leucocytes vary in size from that of a large lymphocyte to cells two or three times that size. The cytoplasm in those cells that contain only a few eosinophilic granules is slightly basophilic and with azure II eosin stains a faint blue similarly to the cytoplasm of the lymphocytes. In cells gorged with granules the basophilic property of the cytoplasm cannot be detected. The eosinophilic granules are coarse, round, quite uniform in size, and stain intensely with eosin. In the majority of these cells the granules are closely crowded together, while in others they are more thinly scattered. An occasional cell is found with only a few granules in it. The granules are usually distributed throughout the cytoplasm, but in quite a large number of eosinophilic leucocytes a small portion of the cytoplasm is free from granules, a feature which Weill ('13) observed in some of the eosinophilic cells in the thymus of rat and man. This non-granular portion has the appearance of a vacuole and is usually located near the nucleus. Eosinophilic granules lying outside of cells were also found, although these are not numerous. The free granules are usually loosely arranged in groups or strung along the course of blood-vessels.

The shape of the eosinophilic leucocytes varies. Some are round, while others are more or less irregular in outline. A small number were found with blunt processes which indicate amoeboid movement, a property common to most leucocytes.

A significant feature of the eosinophilic leucocytes found in the thymus is the form, size, and structure of their nuclei. In the large majority of these cells the nuclei are round, more or less dented, or crescent, i.e., mononuclear,⁵ while in some the nuclei are lobed or typically polymorphonuclear. All intergrades between the round and the lobed nuclei can be found. In the mononuclear cells the nucleus is generally eccentrically located in the cytoplasm. A few eosinophilic granules may be scattered over that portion of the nucleus nearest the surface of the cytoplasm, while in many cells the nucleus is crowded entirely to the surface of the cytoplasm, which causes it to stand out conspicuously among the eosinophilic granules. In the mononuclear eosinophilic leucocytes the nuclei generally range in size from that of the nuclei on the medium and large-sized lymphocytes. An occasional one is found in which the nucleus is no larger than that in the smaller lymphocytes. The structure of the nuclei varies somewhat in that the larger nuclei are generally a little paler than the small nuclei. Most of the chromatin is in the form of irregularly shaped granules of variable size, although some is arranged in threads. Some chromatin granules apparently adhere to the nuclear membrane, while some are scattered throughout the nucleoplasm, which gives the nucleus more or less a checkered appearance. In the small and usually in the medium-sized nuclei the chromatin granules are more thickly scattered than in the large nuclei. This manner of distribution of the chromatin accounts for the greater density of the smaller nuclei found in some of the eosinophilic leucocytes. All grada-

⁵ Eosinophilic myelocyté is the term used by most investigators for the mononuclear eosinophilic leucocyte found in the thymus. Since 'myelocyte' literally means a marrow cell and more specifically a granular marrow cell, it seems to be an inappropriate term to use for cells formed in the thymus, even though the two are structurally alike. The term 'mononuclear eosinophilic leucocyte' will, therefore, be used instead of 'eosinophilic myelocyte.'

tions in the size of the nuclei from small to large, and in the density of the nuclei, from dark to light, are present.

A comparison of the nuclear characteristics between the nuclei in the mononuclear eosinophilic leucocytes and in the lymphocytes shows that their structure is the same, although the form of the nuclei of the eosinophilic cells may vary considerably (from round to crescent shape), while the nuclei of the lymphocytes are quite uniformly round.

An occasional eosinophilic leucocyte in mitotic division can be found. However, since mitoses of these cells are only seldom found, the number of eosinophilic leucocytes arising from pre-existing cells of this type seems to be small. Weill ('13) found that mitotic figures in eosinophilic cells in the thymus of the rat and man are quite numerous, thus indicating that the number of these cells arising from their proliferation is considerably increased.

The facts presented above leave no doubt in my mind concerning the origin of the mononuclear eosinophilic leucocytes in the thymus. The identical structure of the nuclei of both the mononuclear eosinophilic leucocytes and the lymphocytes; the variable number of granules in the eosinophilic cells, ranging in number from very many to a few, in the latter of which the basophilic property of the cytoplasm is easily recognizable, and the presence of mitotic figures in some of the eosinophilic cells are features that point to only two sources of origin for these cells, namely, from the lymphocytes and from pre-existing mononuclear eosinophilic leucocytes. As was stated, polymorphonuclear eosinophilic leucocytes are also present in the thymus, although they are much less numerous than the mononuclear type. Some of these may have entered the intercellular spaces of the thymus from the blood by migrating through the wall of blood capillaries. Others are undoubtedly derived from the mononuclear eosinophilic leucocytes through a transformation of its nucleus. All intergrades from the round to the lobed nucleus is evidence sustaining this view. The structure of the nucleus changes somewhat in its transformation to the lobed condition. It becomes darker or more dense and is then identical in structure to the

nucleus in the eosinophilic leucocytes in the circulating blood. Also, a fact worthy to be noted is that there is no general degeneration of these cells in the thymus, so that the only outlet for those formed in the thymus is the blood.

Although the origin of eosinophilic cells from lymphocytes has been observed by several investigators, only a few have expressed the view that the thymus in normal postnatal mammals studied by them is a source of eosinophilic leucocytes in the blood. Weill ('13), who made a careful study of thymus glands of normal full-grown rats and of four men, concluded that the thymus must be regarded as one of the organs producing granular leucocytes. According to him, the thymus in man is a source of all the different types of granular leucocytes in the blood, while in the thymus of the rat only eosinophilic and basophilic leucocytes are formed, the latter only in the interlobular connective tissue. Weidenreich ('12), who investigated the same human material used by Weill, also arrived at the same conclusions concerning the granular leucocytes as did Weill. Also Schaffer ('93), believes that the thymus of rabbits and cats has an hematopoietic function.⁶ To what extent the thymus in postnatal pigs functions as a source of polymorphonuclear eosinophilic leucocytes before its period of involution is difficult to determine. Taking into consideration the large size of the thymus in the young adult hogs and the relatively large number of mononuclear eosinophilic leucocytes that are found in each section, it would at first sight appear that this organ is a source of a considerable number of these cells in the circulating blood. There is in fixed material no way of determining the duration of time necessary for a mononuclear eosinophilic leucocytes to change into one of the lobed type, which is the stage at which they enter the circulating blood under normal conditions. The comparatively small number of polymorphonuclear eosinophilic leucocytes in the thymus is no index as to the rapidity of the nuclear transformation of the eosinophilic cells, for after transformation they may remain in the intercellular spaces only a short time before entering

⁶ See historical sketch, page 24.

the blood stream. The extent to which the thymus functions as a source of eosinophilic leucocytes is, therefore, undetermined.

Ghika ('01) was the first to call attention to the presence of neutrophilic cells in the pathologic thymus of man, but Weill ('13) was the first investigator to pay special attention to them. He found that in the thymus of normal men fifteen to thirty-seven years old, the neutrophilic leucocytes are as numerous as the eosinophilic leucocytes. The majority of these cells are mononuclear (identical in structure to the neutrophilic myelocytes in bone-marrow), but some have a polymorphic nucleus. All gradations in the shape of the nucleus, from the round to the lobed type, are found in these cells. In the thymus of the rat he was unable to demonstrate neutrophilic cells.

In the thymus of the pig neutrophilic cells could not be demonstrated with the technical methods employed. After failure to demonstrate them in sections, smear preparations of fresh macerated thymus were made and stained with Wright's and Hastings-Nocht's blood stains. The 'drying' method of fixing leucocytes is one of the best methods for fixing the granules in the granular leucocytes, although the nucleus is poorly preserved. It is true that by macerating fresh thymus the content of injured blood-vessels will mix with the parenchyma of the thymus so that in a smear preparation one might expect to find an occasional polymorphonuclear eosinophilic leucocytes which was derived from the blood. Only a few were found in nine smear preparations that were made. The manner in which the hogs were killed (stunned, then immediately bled) undoubtedly accounts for the small number found. The thymus was thoroughly drained of its blood. If neutrophilic leucocytes were formed in the thymus of the pig, as is the case in the thymus of man (Weill), in smear preparations, with granules well preserved, all the developmental stages (from the round to the lobed nucleated type) should have been found. No mononuclear neutrophilic leucocytes were found. I am, therefore, of the opinion that no neutrophilic leucocytes are formed in the thymus of adult hogs. Unfortunately, no smear preparations were made from the thymus of the young pigs.

Portions of the thymus fixed in absolute alcohol revealed the presence of cells containing basophilic granules. As it is desired to further investigate the character of these cells by methods not applicable to fixed material, a report of them will be given at some future time.

In the thymus of postnatal pigs no traces of the formation of red blood-cells were found. This fact is of interest in that in the thymus of the later developmental stages of pig embryos Bardscher ('15) found that nucleated red blood-cells occurred in both the parenchyma of the lobules and in the interlobular connective tissues. These also were derived from the lymphocytes.

The formation of granular leucocytes in the thymus of postnatal mammals is significant from three points of view, namely, 1) it unquestionably disproves the theory of Ehrlich and his followers that the bone-marrow, in normal conditions and during postnatal life, is the only source of the granular leucocytes found in the blood; 2) it bespeaks for the thymus a function that has, up to the present time, not been generally attributed to it, and, 3) it indicates that the lymphocytes (especially the large lymphocytes) in the thymus have, to a limited extent at least, the potentiality of the premyelocytes (myeloblast, hemoblast, primitive blood-cell, 'lymphocyte') in the bone-marrow in so far that they are capable of developing into some or all (perhaps variable in different mammalian species) the types of the granular leucocytes found in the blood. The last point also is additional evidence that the thymic cells are real lymphocytes instead of modified endothelial cells, as held by Stöhr ('06).

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Resumen por el autor, Homer B. Latimer
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El peso de las vísceras de la rana común.

El autor ha empleado cincuenta y nueve ejemplares de la rana leopardo (*Rana pipiens*), treinta de los cuales se habían conservado previamente en formol; los otros veinte y nueve fueron cloroformizados antes de pesarlos. Se pesó cuidadosamente cada rana; después se determinó el peso del corazón, bazo, pulmones, tubo digestivo (incluidos el esófago, estómago, e intestinos grueso y delgado), hígado, páncreas, cuerpos adiposos, riñones y gonadas. Los pesos de cada órgano se redujeron a tantos por ciento del peso total. El corazón forma el 0.46 por ciento del peso total de la rana. El peso medio del bazo constituye el 0.03% en los individuos conservados y el 0.17% en los pesados en estado fresco. Los pulmones forman el 0.85% y el hígado el 3.38% del peso total. El tubo digestivo de los ejemplares frescos constituye el 3.6799% y en los conservados el 2.6813% del peso total. El peso medio del páncreas es el 0.09%. Los riñones forman el 0.4596% del peso de los ejemplares frescos y el 0.7176% del de los conservados.

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THE WEIGHTS OF THE VISCERA OF THE COMMON FROG¹

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The relative weights of the viscera as well as the rate of growth of the human and of the white rat have been carefully investigated, but so far as I know but very little has been done on the weights of the various organs of other species. Welcker and Brandt ('03) have investigated a very small number of two species of frog (*Rana esculentia* and *Rana temporaria*) and a number of other animals getting the relative weights of almost all of the organs. Donaldson has determined the relative weight of the brain and spinal cord of the leopard frog and the bullfrog, but not of the other organs. The frog is so frequently used for study that it seemed as though the percentage weights of the individual viscera might be of some value.

The first ten frogs were weighed by Mr. Cedric H. Nelson, and I wish to express my thanks to him for his careful and accurate work.

MATERIAL AND METHODS

The frogs used were the common leopard frog (*Rana pipiens*) and were secured from a dealer in Chicago. The first thirty specimens were shipped, preserved in formalin, while the last twenty-nine were sent alive and kept in a tank with free access to running water from about the middle of June till they were used. The first twenty-five of the preserved specimens were weighed to a milligram, then carefully opened and the viscera dissected out. The viscera of frogs nos. 27 to 31, inclusive, were weighed in weighing bottles to one-tenth of a milligram. When

¹Studies from the Zoölogical Laboratory of the University of Nebraska, No. 124.

the preserved frogs were opened along the midventral line, the body cavity and the lymph sacs along the dorsal side under the skin contained large quantities of the formalin solution, so the frogs were opened and washed out with tap-water and the excess water removed with absorbent paper toweling before the initial weighing. In the first frogs, where the weighing bottles were not used, the frog and the dissected organs were kept in a closed glass container. In both the preserved and the fresh specimens the mesenteries were cut as close as possible to the organs. In removing the digestive tract the esophagus was severed as close as possible to the glottis and the rectum was cut at the point of the attachment of the urinary bladder.

When the fresh specimens were studied each frog was chloroformed, then the excess mucus was washed off and the skin dried with paper toweling. The frog was then put in a closed container and weighed to one-tenth of a milligram. In dissecting out the organs the frog was held over the dish in which it was weighed so that all blood which escaped might be retained for the second weighing. The organs as soon as dissected out were held a moment to allow as much blood as possible to escape, they were then placed in the weighing bottles and weighed to a tenth of a milligram. The blood which escaped during the dissection and the remainder of the frog were carefully weighed thus giving the net body weight (not given in the tables). The percentage of error for each frog was calculated by adding to this net body weight the sum of the various viscera. This sum was then subtracted from the gross body weight and the difference or actual loss, divided by the total weight of the frog, giving the percentage of error. The percentage of error for some of the earlier frogs was rather large, but still I feel that this should not reflect on the value of the rest of the data, for the individual organs were not allowed to dry and the blood was permitted to escape from the organs and the frog's body after the initial weighing. During the later part of the weighing the percentage of error varied from 0.57 per cent to 1.08 per cent. In the weighings of the preserved specimens it ran as high as 5 per cent.

PERCENTAGES OF THE INDIVIDUAL VISCERA

Table 1 shows the percentages of the thirty preserved specimens, and table 2 that of the twenty-nine freshly killed specimens. The second column gives the total weight, in grams, of each frog before the removal of any of the organs. The variation in weight of both the fresh specimens and the preserved specimens shows that this lot of frogs is a random selection. This variation is from 19.095 grams to a maximum of 56.7866 grams. The other columns represent the percentage weight of the various organs. In each frog the weight of each organ was divided by the total body weight, and this quotient is expressed in terms of percentage. The average is the average of the percentages of the organs.

THE HEART

It will be noticed that the first five frogs, both the males and the females, in table 1 have a lighter heart than the other frogs in the same table. This may be explained by the fact that in removing the hearts from these specimens the sinus venosus was opened and a part of the contained blood escaped. Frog no. 28 in table 1 has a lighter heart more nearly resembling the first ten frogs, for the heart of this frog was accidentally opened and a part of the blood escaped. These smaller percentages correspond more nearly to the results obtained with the freshly killed frogs (table 2) where the blood was drained out as much as possible. The average for the first ten frogs in table 1 is 0.548 per cent, while the average for all the preserved specimens is 0.7179 per cent for both the males and the females. Probably the percentage for the fresh specimens is more nearly correct, for in these frogs the blood was drained out. The average for the males is 0.4354 per cent and for the females, 0.4787 per cent, or an average for all the fresh specimens of 0.4637 per cent. Jackson ('13) finds that the heart in the one-year-old white rat is 0.450 per cent for the male and 0.492, for the female. Vierordt, as quoted by Jackson, gives 0.46 per cent for the adult human heart, and Welcker and Brandt ('03) give 0.66 per cent for the

TABLE 1

Total weight in grams of the preserved frogs and the percentages of the individual organs

NUMBER	TOTAL BODY WEIGHT	HEART	SPLEEN	LUNGS	DIGES- TIVE TRACT	LIVER	PAN- CREAS	FAT BODIES	KID- NEYS	GONADS
A: Male frogs										
	<i>grams</i>									
2	32.640	0.597	0.024	1.042	2.190	5.085	0.061	0.781	0.744	0.043
4	36.010	0.569	0.025	0.603	1.844	4.304	0.031	0.558	0.766	0.063
7	31.520	0.666	0.032	1.770	2.243	4.124	0.060	0.054	0.714	0.095
8	24.250	0.746	0.023	0.878	2.598	3.225	0.082	0.165	0.755	0.107
10	26.850	0.566	0.048	1.162	2.118	4.114	0.067	0.194	0.562	0.104
12	31.110	0.980	0.022	1.051	2.282	3.285	0.093	0.450	0.768	0.099
13	37.195	0.594	0.147	0.594	3.540	4.186	0.077	0.094	0.578	0.131
14	19.095	0.508	0.031	1.178	2.906	4.289	0.130	1.492	0.822	0.041
15	30.380	0.625	0.032	1.619	2.287	3.706	0.072	0.158	0.743	0.102
18	26.090	0.670	0.038	1.636	2.453	3.909	0.084	0.544	0.758	0.091
19	30.912	0.989	0.022	1.035	2.199	3.312	0.058	0.109	0.724	0.071
23	26.352	1.119	0.064	0.717	2.246	4.811	0.087	1.457	0.781	0.098
24	30.940	0.943	0.054	0.953	2.055	3.652	0.106	0.236	0.610	0.145
25	29.075	0.601	0.024	0.918	2.321	3.748	0.079	0.116	0.625	0.137
26	28.335	0.991	0.042	0.751	2.629	4.026	0.112	0.617	0.871	0.112
27	25.725	0.7572	0.0548	1.0864	3.1144	3.5840	0.0754	0.6064	0.7168	0.1076
28	19.910	0.4811	0.0250	1.0241	3.4957	3.2240	0.0502	0.1356	0.6927	0.1009
29	27.300	0.8135	0.0124	0.5161	2.6721	3.7655	0.1373	0.2945	0.7252	0.0725
30	22.810	0.7189	0.0276	1.0578	3.1964	4.5637	0.0758	0.3217	0.9074	0.1416
31	19.890	0.7888	0.0231	0.9205	1.8401	3.4972	0.0809	0.1784	0.7390	0.1432
Average		0.7361	0.0385	1.0256	2.5114	3.9205	0.0809	0.4281	0.7301	0.1002
B. Female frogs										
1	31.300	0.271	0.022	0.575	2.661	2.508	0.038		0.584	9.281
3	24.930	0.501	0.028	0.582	2.507	3.249	0.060	0.140	0.602	6.759
5	23.567	0.492	0.022	0.760	2.847	5.388	0.098	1.006	0.666	0.552
9	24.830	0.487	0.024	0.713	2.807	3.705	0.077	0.813	0.660	0.608
11	29.720	0.572	0.034	0.636	2.301	4.777	0.050	0.077	0.703	10.766
16	22.855	0.958	0.043	0.682	3.390	3.692	0.087	0.927	0.848	0.647
17	26.410	0.931	0.049	0.791	3.222	4.468	0.106	0.072	0.738	0.484
20	30.455	0.755	0.032	0.482	3.424	3.257	0.091	0.190	0.633	11.081
21	24.320	0.834	0.024	0.855	3.289	4.440	0.152	0.949	0.769	0.563
22	20.201	0.717	0.054	0.930	3.762	3.420	0.118	0.371	0.725	0.678
Average		0.6518	0.0332	0.7006	3.0210	3.8904	0.0877	0.4545	0.6928	4.1419

TABLE 2

Total weight in grams of the freshly killed frogs and the percentages of the individual organs

NUMBER	TOTAL BODY WEIGHT	HEART	SPLEEN	LUNGS	DIGER- TIVE TRACT	LIVER	PAN- CREAS	FAT BODIES	KID- NEYS	GONADS
A. Male frogs										
	<i>grams</i>									
32	32.6089	0.4106	0.0886	0.7317	3.8271	2.6667	0.0956	1.8728	0.5443	0.0089
33	41.9013	0.5004	0.0756	0.5913	3.9805	3.1645	0.1076	1.1474	0.4725	0.1455
38	35.9506	0.4297	0.0489	0.9229	3.9053	2.0444	0.0762	0.3930	0.4036	0.0851
43	47.2026	0.3760	0.1564	1.0381	3.5540	2.9100	0.1271	0.9427	0.4228	0.0781
44	34.5966	0.4176	0.0751	0.9298	3.1315	2.7710	0.1112	2.1129	0.4306	0.0942
46	40.9336	0.4067	0.1954	0.9112	3.8916	3.7529	0.1126	0.5643	0.4263	0.1328
48	35.4050	0.5547	0.0844	0.7852	3.5192	2.5711	0.0816	1.0139	0.4530	0.0917
49	37.5476	0.4013	0.3614	1.1241	3.7011	3.0137	0.0783	0.7324	0.4293	0.1134
53	29.6120	0.5014	0.3836	0.7260	2.9109	2.7417	0.0898	0.8412	0.3343	0.2117
57	25.3576	0.3647	0.3848	0.7851	2.6118	2.4276	0.0780	0.3813	0.4302	0.1762
Average		0.4354	0.1854	0.8545	3.5033	2.8064	0.0959	1.0002	0.4347	0.1138
B. Female frogs										
34	47.3963	0.7327	0.0959	0.7540	5.3460	3.6253	0.0997	2.0750	0.5025	1.4726
35	42.9022	0.4836	0.0766	0.4873	3.6501	2.4492	0.0946	0.3368	0.4009	0.4836
36	42.7348	0.6743	0.1879	0.9298	6.0302	2.7766	0.1411	0.6996	0.5782	0.9463
37	31.1532	0.5151	0.0570	0.7726	3.7174	2.0184	0.1197		0.4208	0.4462
39	56.7866	0.4682	0.0695	0.9685	4.2809	4.0416	0.1179	0.6730	0.4863	1.3381
40	32.5370	0.4348	0.4929	0.5317	3.5159	2.2897	0.1131	0.2323	0.5609	0.5415
41	43.8326	0.5060	0.1088	0.6517	4.8229	2.6551	0.1421	0.6686	0.4863	0.8272
42	45.8056	0.4165	0.1200	0.6396	3.2749	2.9723	0.0927	1.2906	0.5853	0.7108
45	41.2186	0.2511	0.1834	0.8111	3.4236	3.7230	0.0984	1.4036	0.4476	1.7761
47	45.4836	0.3693	0.2508	0.8334	4.1773	3.4408	0.0921	0.8429	0.4845	0.6773
50	37.2694	0.4778	0.1467	0.8274	3.6839	3.5863	0.1196	1.7105	0.4513	0.8867
51	35.5636	0.4549	0.0795	0.6537	2.9383	2.5773	0.0911	1.2687	0.4957	1.5560
52	35.5981	0.4958	0.1162	1.0031	3.2080	2.9934	0.1064	0.1376	0.4157	1.6571
54	33.6436	0.3611	0.2621	0.7442	3.3150	2.2143	0.0772	0.1551	0.5261	2.0125
55	31.1160	0.5238	0.1182	0.6398	2.9598	2.9415	0.0842	0.1253	0.4965	1.0123
56	33.9786	0.5194	0.3499	0.7960	3.3424	3.0840	0.0835	0.4761	0.4502	2.3405
58	30.6408	0.3795	0.0597	0.8877	2.8654	2.4555	0.0528	0.3655	0.3524	2.6503
59	32.7326	0.4475	0.1973	1.0601	3.3290	2.8247	0.0736	0.1313	0.3922	1.4147
60	24.9564	0.5830	0.2428	0.5449	3.8026	2.1232	0.0552	0.1606	0.4499	0.4928
Average		0.4787	0.1692	0.7649	3.7728	2.8838	0.0976	0.6712	0.4728	1.2233

adult human heart. Welcker and Brandt find the heart in two specimens of *Rana esculenta* forming 0.28 per cent and in two specimens of *Rana temporaria*, 0.43 per cent of the body weight. On the whole, there is a striking similarity in weight of the hearts of the fresh specimens and the human heart and the hearts of the white rats.

THE SPLEEN

The spleen is fairly constant in the first table, varying from a maximum of 0.147 per cent in no. 13 to a minimum of 0.022 per cent in four specimens. The average for all the preserved specimens is 0.0368 per cent. In table 2 the average weight of all the spleens is 0.1748 per cent. The marked difference is due in part at least to the number of 'enlarged spleens' in the fresh material and possibly to a lesser, though unknown, extent to the effect of the preservative. Some of these spleens are being saved for study. The minimum percentage given in table 2 is 0.0570 for frog no. 37, and this is two and a half times as heavy as the smallest spleen in table 1. The averages for both tables are very much less than that given by Vierordt and also by Jackson for the human or for the white rat. Vierordt gives 0.25 per cent for the adult human spleen, and for the albino rat Jackson gives 0.396 per cent for the male and 0.327 per cent for the female. Welcker and Brandt find in the two specimens of *R. esculenta* the spleen forming 0.17 per cent and in *R. temporaria* 0.09 per cent.

THE LUNGS

The weight of the lungs, as I find them forming 0.7958 per cent in the freshly killed frogs and 0.9173 per cent in the preserved, corresponds more nearly to Jackson's data for the white rat, as he gives 0.93 per cent for the male rats and 0.77 per cent for the female. According to Vierordt, the adult human lungs are 1.50 per cent of the total weight. Welcker and Brandt, in the four frogs weighed, find an average of 1.16 per cent, but they included the larynx and trachea in their weights. The weights given for the frogs in this paper are for the lungs only. In removing the lungs each lung was dissected away at its attachment to the trachea.

THE DIGESTIVE TRACT

The digestive tract, including the esophagus, stomach, and the large and small intestine, averages 2.6813 per cent for the preserved specimens and 3.6799 per cent for the fresh frogs. The digestive systems of both the fresh and the preserved specimens contained but little material. No attempt was made to remove the contents from the digestive tracts of the preserved specimens, but the figures given for the fresh specimens are the percentages of the digestive tract minus its contents, and yet this figure is 1.37 times heavier than that of the preserved specimens. The fact that these frogs were kept for some time may be the cause of the lighter alimentary canal. They were fed fly maggots on several occasions and they showed no signs of sickness. These percentages are lower than the 5.1 per cent for male rats and the 5.9 per cent for female rats as found by Jackson, or the average of 4.72 per cent of Welcker and Brandt's frogs. Jackson included the mesenteries and pancreas, but not the esophagus, while I included the esophagus, but not the pancreas or the mesenteries. Welcker and Brandt give 2.56 per cent for the adult human male and 2.84 per cent for the female, and Vierordt gives an even lighter weight, as he finds the digestive tract forming but 2.06 per cent in the adult human.

THE LIVER

The results obtained from weighing the liver and the gall-bladder resemble the percentages of the digestive tract in that they are lighter than those given for the rat and heavier than the data given for the human. Jackson gives 4.42 per cent for male and 4.24 per cent for female albino rats, Vierordt, 2.75 per cent for the adult human, and Welcker and Brandt give 3.09 per cent for male and 2.68 per cent for the human female bodies. Welcker and Brandt find a heavier liver in their four frogs, for they obtained an average of 3.95 per cent. I find that the average for all of the frogs is 3.3825 per cent. The liver and gall-bladder average a little over 1 gram, or 1.368 times heavier in the freshly killed than in the preserved specimens. The averages are, 3.9104 per cent for the fresh and 2.8571 per cent for the preserved frogs.

THE PANCREAS

The pancreas varies less than the liver and the digestive tract, the averages are 0.0831 per cent for the preserved frogs and 0.0970 per cent for the fresh, thus making the second 1.16 times heavier. Welcker and Brandt give 0.17 per cent and 0.08 per cent for their two groups of frogs, 0.15 per cent for the female and 0.14 per cent for the adult human male. Vierordt gives 0.15 per cent for the adult human pancreas.

THE FAT BODIES

The fat bodies naturally vary to a marked degree, and their variation seems to be independent of the relative weight of the liver and the digestive tract. If the weights of these two organs are low because of inanition, the specimens with small fat bodies should have the smaller percentage weight of the digestive tract and liver, but this does not seem to be the case.

THE KIDNEYS

The kidneys, including the adrenals, are quite constant in weight in each table, although there is a marked difference between the two tables (tables 1 and 2), the preserved specimens being 1.56 times heavier. It would seem that so large and so constant a difference must be due to the action of the preservative. Vierordt finds the adult human kidney forming 0.46 per cent, and Jackson finds 0.954 per cent for the male white rats and 0.980 per cent for the female rats. Welcker and Brandt give 0.37 per cent and 0.42 per cent for the frogs, while I find an average of 0.4596 per cent for the fresh specimens and 0.7176 per cent for the preserved frogs.

THE GONADS

The variation in the ovaries and the contained ova is not at all surprising. The first ten females given in table 2 were weighed early in July and then there was an interval of ten days before the weighing was resumed. The increase in the size of the ovaries is pronounced. A complete seasonal variation in the

size of the gonads of the frog would be interesting. There were only two males in the last lot, so the variation in the testes does not show as well. The testes in the preserved frogs average 0.1002 per cent and in the fresh specimens 0.1138 per cent. In the adult human, according to Vierordt, the testes form 0.080 per cent, and Jackson finds them forming 1.184 per cent in the white rat.

SEX VARIATION IN VISCERA

The difference in the percentage weights of the lungs, the spleen, the digestive tract, and the pancreas in the male and female frogs is shown in table 3. The other organs do not show this constant sex difference. Jackson ('13) and Welcker and Brandt ('03) find the spleen and the lungs heavier in the males. Welcker and Brandt weighed the lungs, trachea, and larynx all together. Both of these papers list a heavier digestive tract for the females. Welcker and Brandt find the male pancreas in the frog heavier, while I find the female heavier.

WEIGHTS OF THE ORGANS ON THE RIGHT AND LEFT SIDES

During the course of the experiment the question of the weights of the organs on the right and left sides arose, and so each of the lungs, the kidneys, and the gonads from several specimens were weighed separately, and the sums of their absolute weights are shown in table 4.

One of the female frogs (No. 16) had but one lung. The trachea turned toward the right, where it terminated in an apparently normal lung. This one lung was supplied with the usual paired blood-vessels and nerves. There was a good deal of variation in the individual specimens, but I could detect no compensation of organs such as a small right lung and a large kidney on the same side. The weights were carefully checked in this manner, but with no definite results. The sums of the weights for all the right kidneys, the left lungs, and so forth do show that the lungs and the kidneys are both heavier on the right side of both the male and the female frogs and that the gonads, are heavier in

both sexes on the opposite side, or on the left side. This is so slight, however, that it was not detected till the sums of the weights were studied.

SUMMARY

1. The hearts of the frogs were found to compose about 0.46 per cent of the total weight of the frog.

2. The spleen forms a little over 0.03 per cent of the total weight of the preserved specimens and a little over 0.17 per cent of the weight of the freshly killed frogs.

3. The average percentage weight of the lungs for all the frogs is 0.8565 per cent.

4. The digestive tract forms 2.6813 per cent of the total weight of the preserved specimens and 3.6799 per cent of the fresh frogs.

5. The liver equals 3.3825 per cent of the total weight for all the specimens.

6. The average percentage weight of the pancreas for all the frogs is 0.09 per cent.

7. The kidneys form 0.4596 per cent of the total weight of the fresh specimens and 0.7176 per cent of the preserved frogs.

TABLE 3

Percentages of the lungs, spleen, digestive tract, and pancreas in male and female frogs

MALES		FEMALES	
Lungs			
<i>per cent</i>		<i>per cent</i>	
20 preserved, average	1.0256	10 preserved, average	0.7006
10 fresh, average	0.8545	19 fresh, average	0.7649
Average	0.9686	Average	0.7428
Spleen			
20 preserved, average	0.0385	10 preserved, average	0.0332
10 fresh, average	0.1854	19 fresh, average	0.1692
Digestive tract			
20 preserved, average	2.511	10 preserved, average	3.021
10 fresh, average	3.5033	19 fresh, average	3.7728
Average	2.8421	Average	3.5136
Pancreas			
20 preserved, average	0.0809	10 preserved, average	0.0877
10 fresh, average	0.0959	19 fresh, average	0.0976
Average	0.0859	Average	0.0942

TABLE 4

Sum of the weights, in grams, of the right and the left organs of the preserved frog

	LUNGS ¹		KIDNEYS		GONADS ¹	
	Left	Right	Left	Right	Left	Right
15 male frogs.....	2.249	2.366	1.553	1.608	0.173	0.149
11 female frogs.....	0.747	0.865	0.886	0.892	0.316	0.235

¹ The testes were weighed from only eleven frogs, the lungs from ten females and the ovaries from but four frogs are included in this table.

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Resumen por el autor, Frank Charles Mann.
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El tracto biliar extra-hepático de los animales doméstico
comunes y animales de laboratorio

El autor ha llevado a cabo el estudio del tracto biliar extra-hepático de once especies de animales provistos de vejiga biliar y cuatro especies desprovistas de este órgano, para determinar: 1) Si el tracto biliar extra-hepático compensa la falta de vejiga biliar y 2) si hay alguna relación entre la presencia o ausencia de vejiga biliar y la distancia que separa al píloro del punto en que entra en el duodeno el conducto biliar común. Los datos obtenidos responden de un modo negativo a ambas cuestiones.

Translation by José F. Nonidez
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THE EXTRAHEPATIC BILIARY TRACT IN COMMON DOMESTIC AND LABORATORY ANIMALS¹

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EIGHTEEN FIGURES

During an investigation of the function of the gall-bladder we (3) were impressed with two points: 1) the great variation in the relation of the component parts of the biliary tract to each other in man and in various species of animals and 2) the difficulty of obtaining data on this phase of comparative anatomy. We shall attempt to present in compact form the comparative anatomy of the biliary tract of animals commonly used in research laboratories. For purposes of comparison the more common domestic animals and a few other species that are not ordinarily used in laboratories have been included. While we are fully aware that descriptions² of the biliary tracts of most of these animals have been previously made, such descriptions are widely scattered, and do not contain the particular data we desire (1, 2, 4, 5, 6, and 8). We hope that our investigation will form a nucleus for the study of comparative anatomy of this region, to which may be added, from time to time, similar facts concerning other species. The prime importance of these data is their bearing on the functional significance of the gall-bladder.

Specimens from several animals of each species that might be useful in the research work were studied. All dissections were

¹ Presented for publication June 28, 1919.

² Several descriptions, some of them quite complete, of the comparative anatomy of the biliary tract are given in the literature. In our search for an anatomic basis for the function of the gall-bladder, however, we were unable to find the desired data. The descriptions given in this article cover only the points considered important for the purpose of the investigation. A study of a large series of species would include many other variations. References to some of the important articles dealing with the biliary tract are added.

done on fresh material. The measurements with few exceptions were taken by one person (Foster) in order to avoid individual variations. It should be emphasized that in research of this nature only the average anatomic condition can be considered. Furthermore, all measurements are relative, as it is impossible to obtain animals all of the same relative size (table 1).

The data considered the most valuable for our purpose are: 1) Length of the common duct; 2) diameter of the common duct; 3) length of the cystic duct; 4) diameter of the cystic duct; 5) capacity of the gall-bladder, and, 6) distance from the pylorus to the entrance of the common bile duct.

Table 2 presents our findings briefly and in comparative terms. It is impossible to compare anatomic points of different species except in general terms.

DISCUSSION

These data emphasize the fact which has been previously noted, that the biliary tract in the various species of animals varies greatly and that it seems impossible to explain the cause or purpose of these variations. Careful embryologic studies have not served to solve the problem (7).

We gained from our work, from the standpoint of the function of the gall-bladder, some knowledge of the relationship of the capacity of the extrahepatic biliary tract in animals without a gall-bladder to the capacity of the gall-bladder in comparable species, and of the distance from the pylorus at which the common bile duct enters the duodenum in species of animals with a gall-bladder, as compared with those without a gall-bladder.

The anatomic variation in the dimensions of the common bile duct has been considered a possible means whereby an animal without a gall-bladder compensates for the lack of it. When we attempted to measure the capacity of the extrahepatic biliary tract in animals without a gall-bladder, we found it difficult to avoid very great errors, particularly in small species. Our measurements seem to prove, however, that there is no relation between the dimensions of the common duct and the presence or absence of a gall-bladder. The comparison of a few species

illustrates this point: The horse, which does not possess a gall-bladder, has a relatively short duct with a large diameter, while the ox, which possesses a gall-bladder, has a duct which, although narrower, is much longer, and its relative capacity is almost as great as that of the horse. The same is true in comparing the deer with the goat and sheep. The relative capacity of the extrahepatic biliary system of the deer, which has no gall-bladder, certainly appears to be no greater than that of the sheep or goat, exclusive of the gall-bladder capacity in the two latter species. In the horse and deer the hepatic duct is comparatively short, but its diameter is large as compared with closely related species having a gall-bladder. The rat and pocket gopher, however, both species without a gall-bladder, have, as a rule, actually longer ducts with narrower lumina as compared with such species as the guinea-pig, rabbit, and striped gopher, all of which have gall-bladders. In the latter species the comparable ducts are relatively no greater than in the species in which the gall-bladder is absent. Thus it would seem that the relative capacity of the extrahepatic biliary tract is little if any greater in species of animals without a gall-bladder than that of the same ducts in comparable species which possess a gall-bladder, and it does not, in any of the species, compensate for the lack of a gall-bladder.

The distance between the pylorus and the entrance of the bile duct into the duodenum was measured because it was thought that there might be a relationship, with regard to alkali control in the duodenum, between the presence or absence of the gall-bladder and bile escape and the acid escape into the intestines. In this connection, however, no differentiation can be made between groups of animals having a gall-bladder and those without one. Examples may be cited as follows: The hepatic duct of the horse enters the duodenum between 10 and 20 cm. from the pylorus, while that of the ox enters between 50 and 70 cm. from the pylorus. On the other hand, the ducts enter the duodenum about from 0.5 to 1.5 cm. from the pylorus in the rabbit, and from 0.4 to 0.8 cm. in the guinea-pig, while in the rat the distance is from 1.5 to 2.5 cm., and in the pocket gopher from 4 to 5 cm.

SPECIES	SEX	WEIGHT	DIAMETER OF COMMON DUCT	LENGTH OF COM- MON DUCT	DIAMETER OF CYSTIC DUCT	LENGTH OF CYS- TIC DUCT	CAPACITY OF GALL-BLAD- DER	DISTANCE FROM PYLORUS TO OPENING OF COMMON DUCT	SEX	SPECIES	WEIGHT	DIAMETER OF COMMON DUCT	LENGTH OF COM- MON DUCT	DIAMETER OF CYSTIC DUCT	LENGTH OF CYS- TIC DUCT	CAPACITY OF GALL-BLAD- DER	DISTANCE FROM PYLORUS TO OPENING OF COMMON DUCT
		kgm.	mm.	mm.	mm.	mm.	cc.	mm.			gm.	mm.	mm.	mm.	mm.	cc.	mm.
Dog.....	M	14.0	3.0	57.0	2.5	27	20.0	43	M	707	2.0	20.0	20.0	1.5	10.0	0.8	6
	M	13.2	2.5	70.0	2.0	22	17.0	55	M	775	2.5	15.0	15.0	1.5	12.0	1.2	8
	F	9.1	3.0	60.0	2.0	17	14.0	45	M	560	2.0	12.0	1.5	12.0	0.8	5	
	F	8.1	2.5	65.0	2.0	11	12.0	40	M	653	2.0	18.0	1.0	1.0	1.2	5	
	M	8.1	2.5	50.0	2.0	24	12.0	42	M	755	2.0	20.0	1.0	1.0	1.0	6	
	Average	10.5	2.7	60.4	2.1	20	15.0	45	Average	690	2.1	17.0	1.3	1.1	1.0	6	
Goat.....	M	20.5	3.5	100.0	3.0	25	15.0	270	F	1500	2.0	33.0	2.0	2.0	10.0	1.5	27
	M	23.6	3.5	110.0	3.0	48	26.0	380	M	1900	1.5	34.0	1.0	15.0	2.0	08	
	M	24.5	4.0	100.0	3.0	55	34.0	310	F	1620	2.5	38.0	2.0	26	1.5	32	
	M	22.0	4.0	100.0	3.0	45	26.0	280	M	1675	2.0	35.0	2.0	14.0	4.0	28	
	M	24.0	4.0	100.0	3.0	52	37.0	300	M	2330	2.0	60.0	2.0	15.0	2.0	40	
	Average	22.9	3.8	102.0	3.0	45	27.6	308	Average	1805	2.0	40.0	1.8	16.0	2.2	31	
Rabbit.....	M	2385	2.5	37.0	1.5	25	3.6	8	F	2050	3.5	26.0	3.0	3.0	18.0	2.0	20
	F	2280	2.5	40.0	2.0	16	3.2	8	F	2040	3.0	37.0	2.5	2.5	14.0	2.5	25
	F	2150	2.5	46.0	2.0	24	2.5	6	F	1890	3.0	16.0	3.0	3.0	11.0	1.5	21
	M	2335	2.0	47.6	1.5	21	2.2	10	F	1650	3.0	35.0	2.0	2.0	12.0	3.0	10
	M	2275	2.0	40.0	1.5	14	2.0	8	F	1575	3.0	28.0	2.0	2.0	8.0	4.0	24
	Average	2285	2.3	42.0	1.7	20	2.7	8	Average	1841	3.1	28.4	2.5	2.5	12.6	2.6	20

Do

Average

Goat....

Average

Rabbit.

Average

Hog.....	M	80	5.0	100.0	2.0	60	28	30	Rat.....	M	330	1.0	20.0			10
	F	86	6.0	95.0	2.0	50	25	35		F	200	1.0	12.0			
	F	73	5.0	90.0	2.0	60	23	35		F	200	1.0	30.0			
	F	136	6.0	100.0	3.0	70	24	40		M	140	1.0	40.0			
	F	125	6.0	95.0	3.0	60	25	38		M	175	1.0	45.0			
	Average	100	5.6	96.0	2.4	60	25	35.6		Average	209	1.0	29.4			
Cow.....	F	365	7.0	40.0	3.0	40	400	500	Pocket gopher.....	M	260	1.0	70.0			50
	F	430	8.0	60.0	4.0	45	575	550		M	270	1.0	50.0			
	F	420	8.0	60.0	4.0	50	200	575		F	225	1.0	70.0			
	F	455	7.0	70.0	3.0	50	400	575		F	325	1.0	55.0			
	F	430	7.0	40.0	3.0	40	375	550		F	270	1.0	55.0			
	Average	420	7.4	54.0	3.4	45	390	550		Average	270	1.0	60.0			
Sheep.....	M	45.0	5.0	95.0	3.0	57	30	300	Striped gopher.....	F	95	1.0	10.0		1—	3
	M	47.0	5.0	110.0	3.0	64	15	280		F	100	1.0	15.0			
	M	47.0	4.0	105.0	3.0	42	37	280		M	90	1.0	15.0			
	M	40.0	4.0	105.0	3.0	32	23	260		M	90	1.0	15.0			
	F	54.0	5.0	115.0	3.0	60	50	320		M	90	1.0	15.0			
	Average	46.6	4.6	106.0	3.0	51	31	288		Average	93	1.0	14.0			

¹ These animals were selected because they were nearest in size in each group. In most instances many more measurements were taken. Three species that were studied, the deer, the horse, and the mouse, are not included. Anomalies were not considered. Many of the measurements were difficult to make, and for that reason some, such as the diameter of the ducts in small species, are only approximately correct. Note the great variations in the measurements even when the different animals were selected.

TABLE 2

Comparative anatomic findings in various species of animals

SPECIES	GALL-BLADDER	COMMON BILE DUCT OR HEPATIC DUCT	CYSTIC DUCT	DISTANCE FROM PYLORUS TO ENTRANCE OF BILE DUCT INTO DUODENUM
Horse	Absent	Hepatic duct short but quite wide	Absent	Short
Ox	Well developed	Common duct long; a good diameter.	Long	Long
Sheep	Well developed	Common duct long; fairly wide diam- eter	Long	Moderate
Goat	Well developed	Common duct long; a good diameter	Long	Long
Deer	Absent	Hepatic duct short but fairly wide	Absent	Moderate
Dog	Well developed	Common duct long; moderate in width	Short	Short
Cat	Well developed	Common duct long; moderate in width	Moderate length; very tor- tuous	Short
Hog	Well developed	Common duct long and wide	Long	Short
Monkey (M. rhesus)	Well developed	Common duct of moderate length and width	Moderate	Short
Rabbit	Thin walled	Common duct long; moderate in width	Moderate	Very short
Guinea-pig	Thin walled	Common duct of moderate length and width	Moderate	Very short
Mouse (white)	Very thin wall- ed	Common duct long; of moderate width	Moderate	Long
Striped gopher (C. tridecem- lineatus)	Well developed	Common duct short and wide	Moderate	Very short
Rat (white)	Absent	Hepatic duct long and narrow	Absent	Long
Pocket gopher (G. bursari- us)	Absent	Hepatic duct very long and narrow	Absent	Very long

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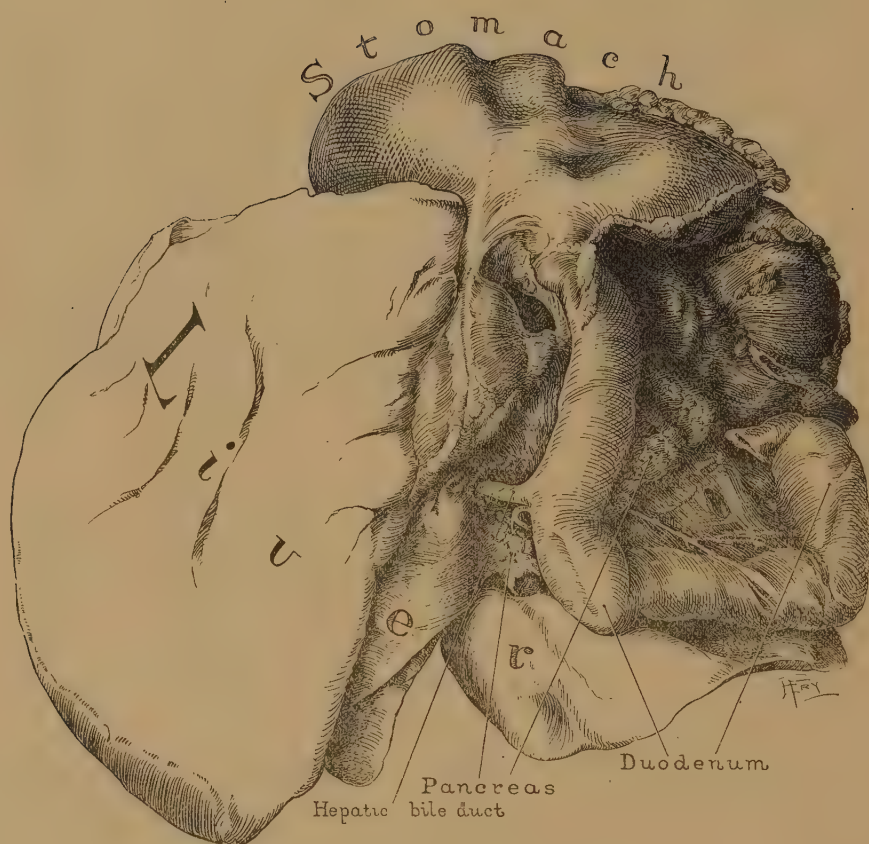


Fig. 1 The biliary tract of the horse



Fig. 2 The biliary tract of the calf



Fig. 3 The biliary tract of the sheep

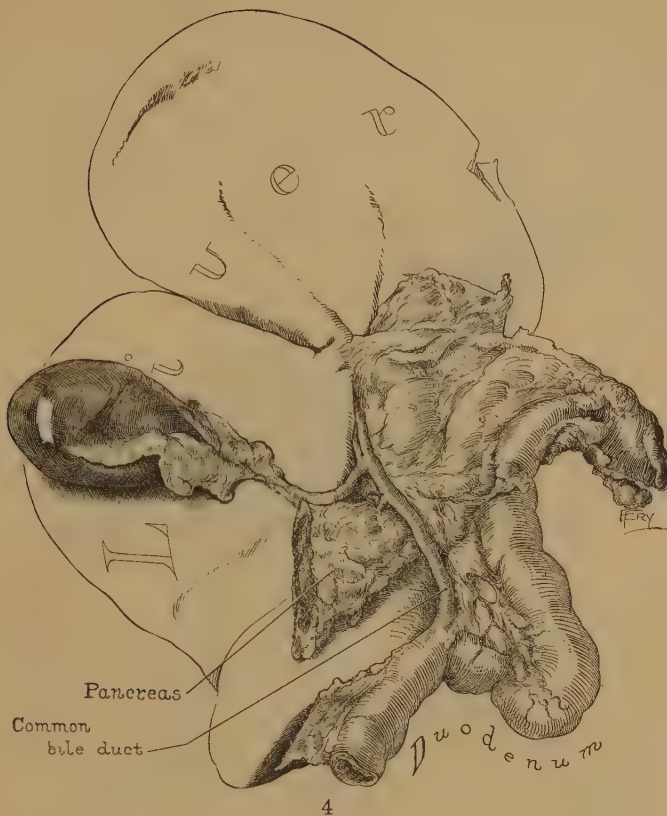


Fig. 4 The biliary tract of the goat.

Fig. 5 The biliary tract of the deer.



Fig. 6 The biliary tract of the dog.

Fig. 7 The biliary tract of the cat.

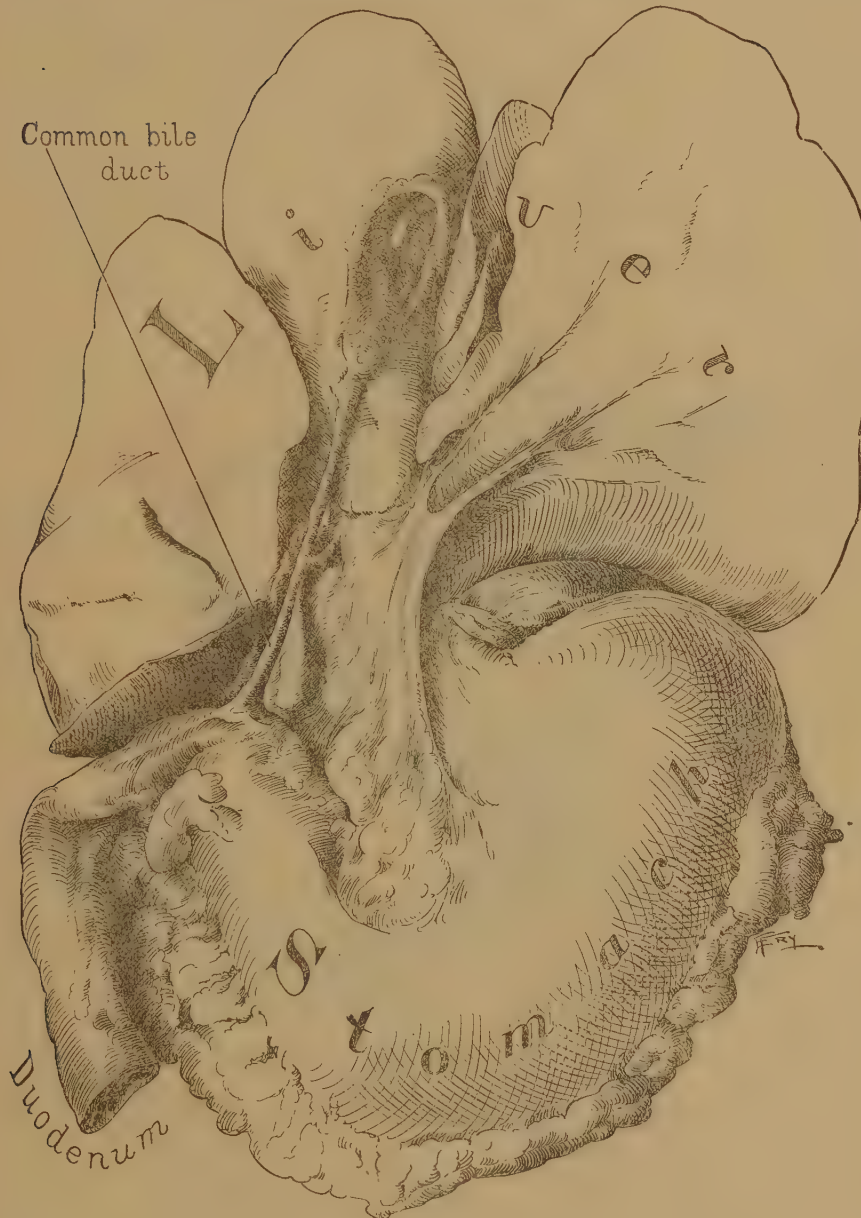


Fig. 8 The biliary tract of the pig

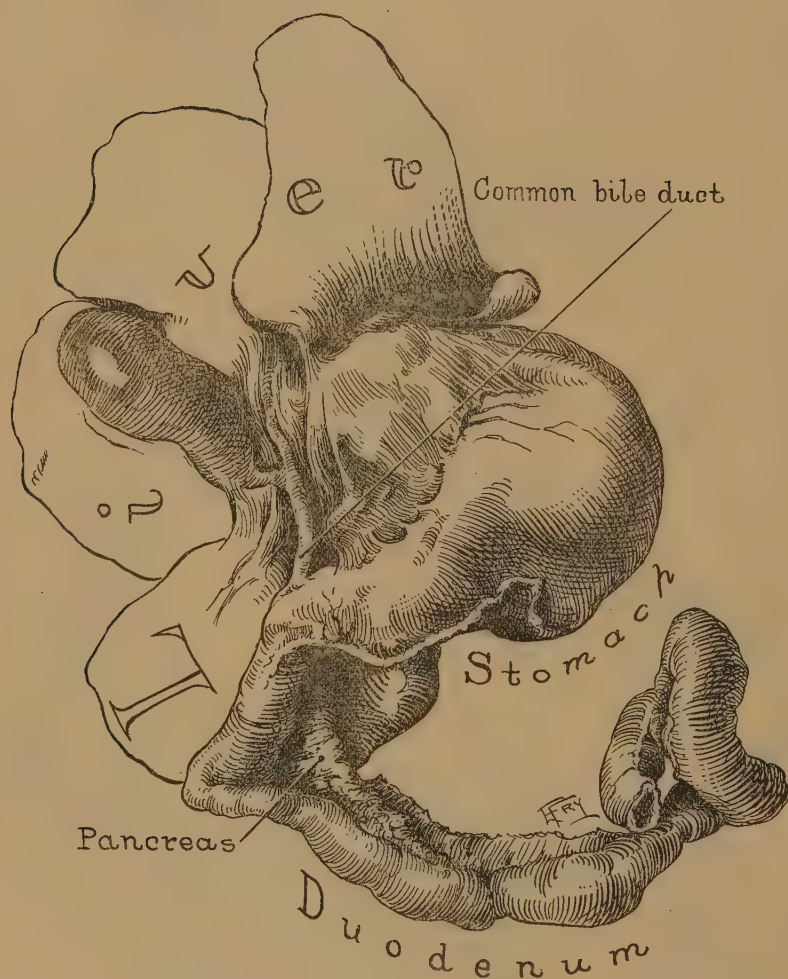


Fig. 9 The biliary tract of the monkey (*M. rhesus*)

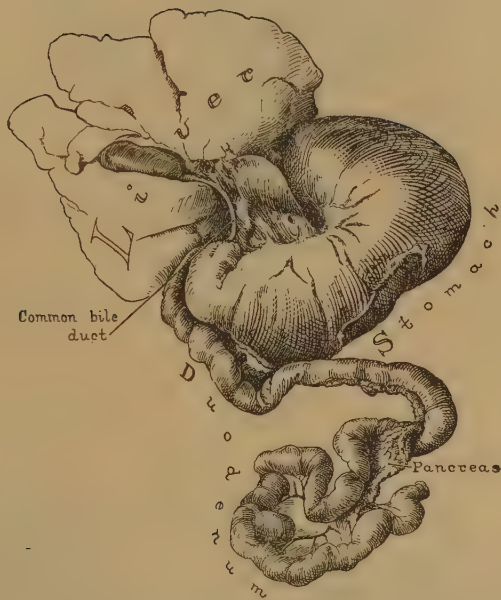
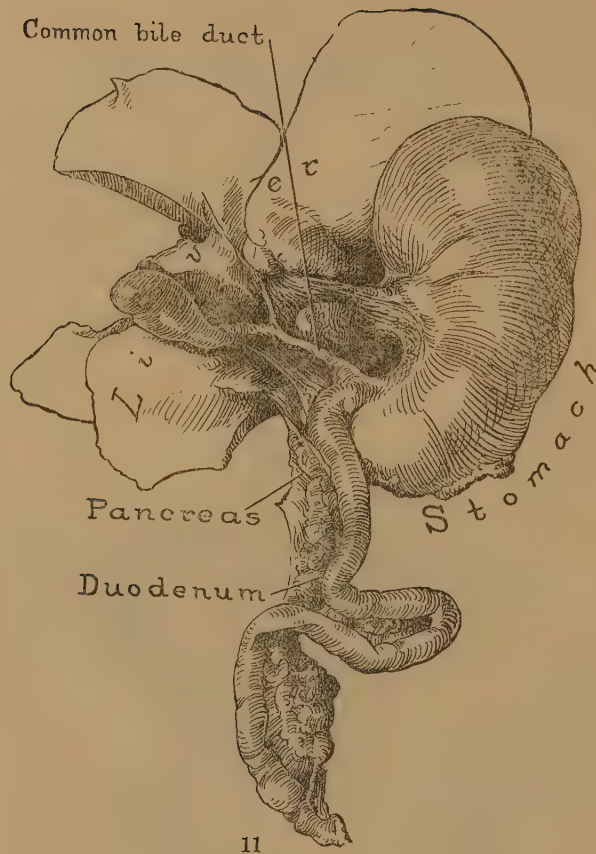
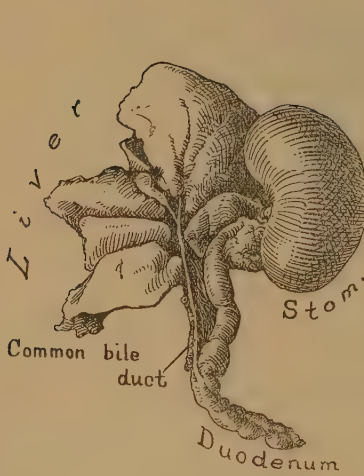


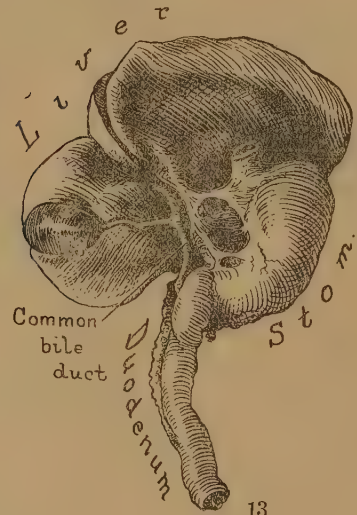
Fig. 10 The biliary tract of the rabbit



11



12



13

Fig. 11 The biliary tract of the guinea-pig.

Fig. 12 The biliary tract of the mouse.

Fig. 13 The biliary tract of the striped gopher (*C. tridecemlineatus*).

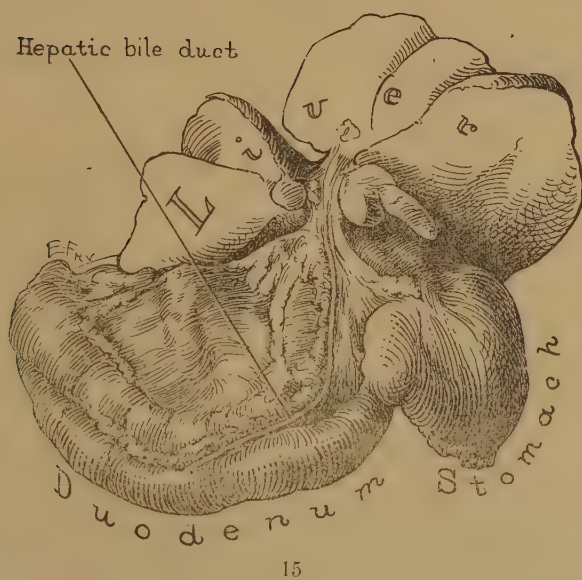
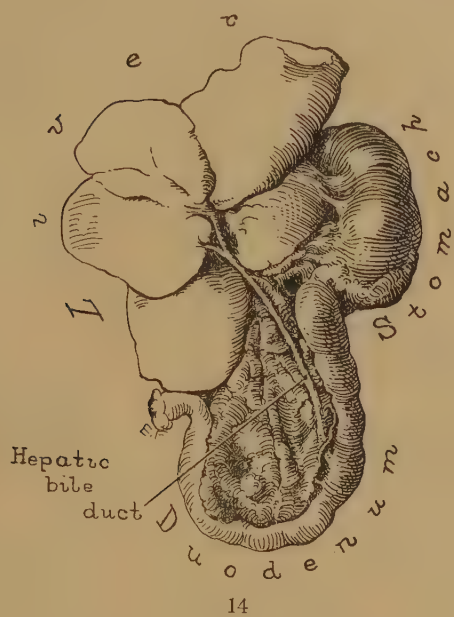


Fig. 14 The biliary tract of the rat.

Fig. 15 The biliary tract of the pocket gopher (*G. bursarius*).

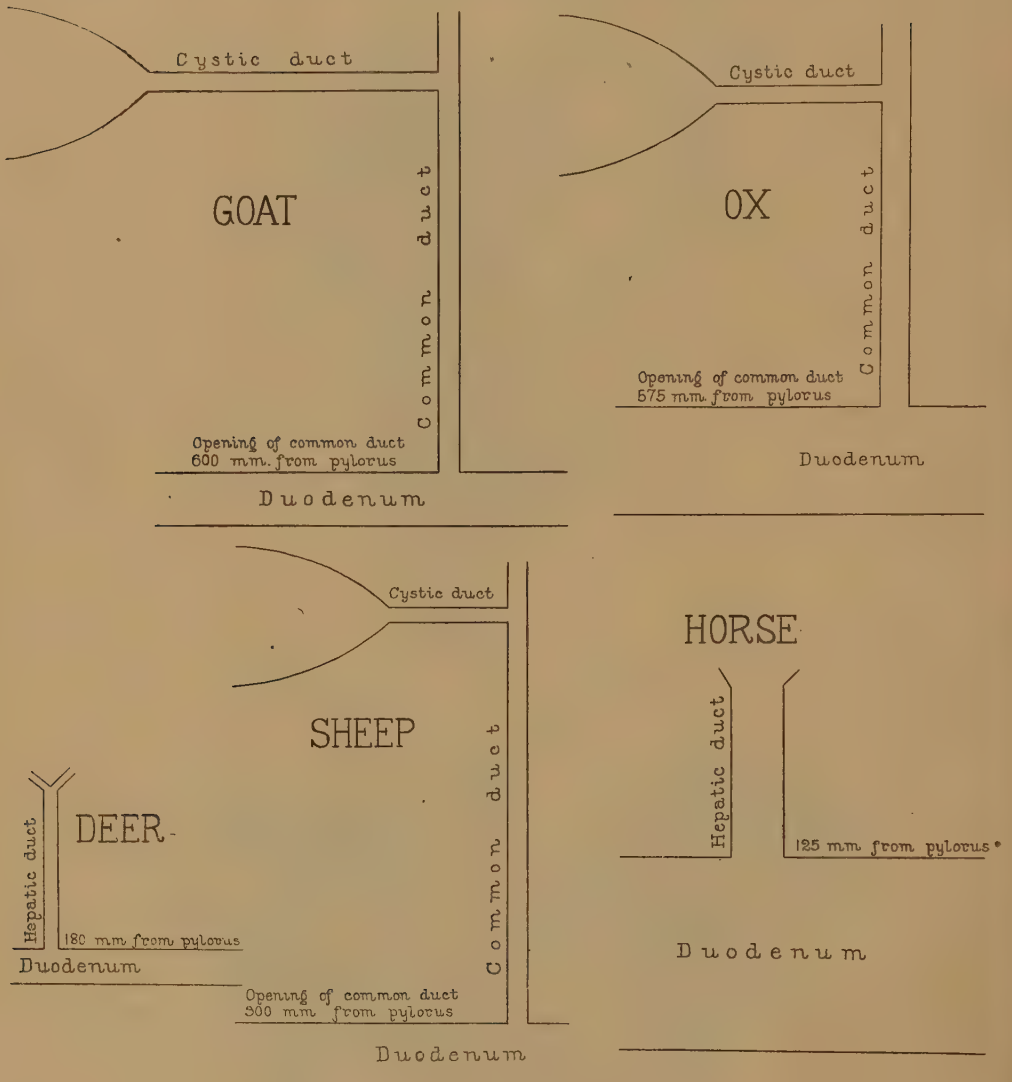


Fig. 16 Diagram showing the exact size and relations of the biliary tract in the horse, ox, sheep, goat, and deer. In comparing the horse and ox, note that the capacity of the hepatic duct of the former does not contain much more bile than the common and cystic ducts of the latter and certainly does not compensate for the lack of a gall-bladder. The same comparison can be made between the other three species. The entrance of the bile duct into the duodenum is relatively closer to the pylorus in the species without a gall-bladder than in those possessing one (compare with figure 17).

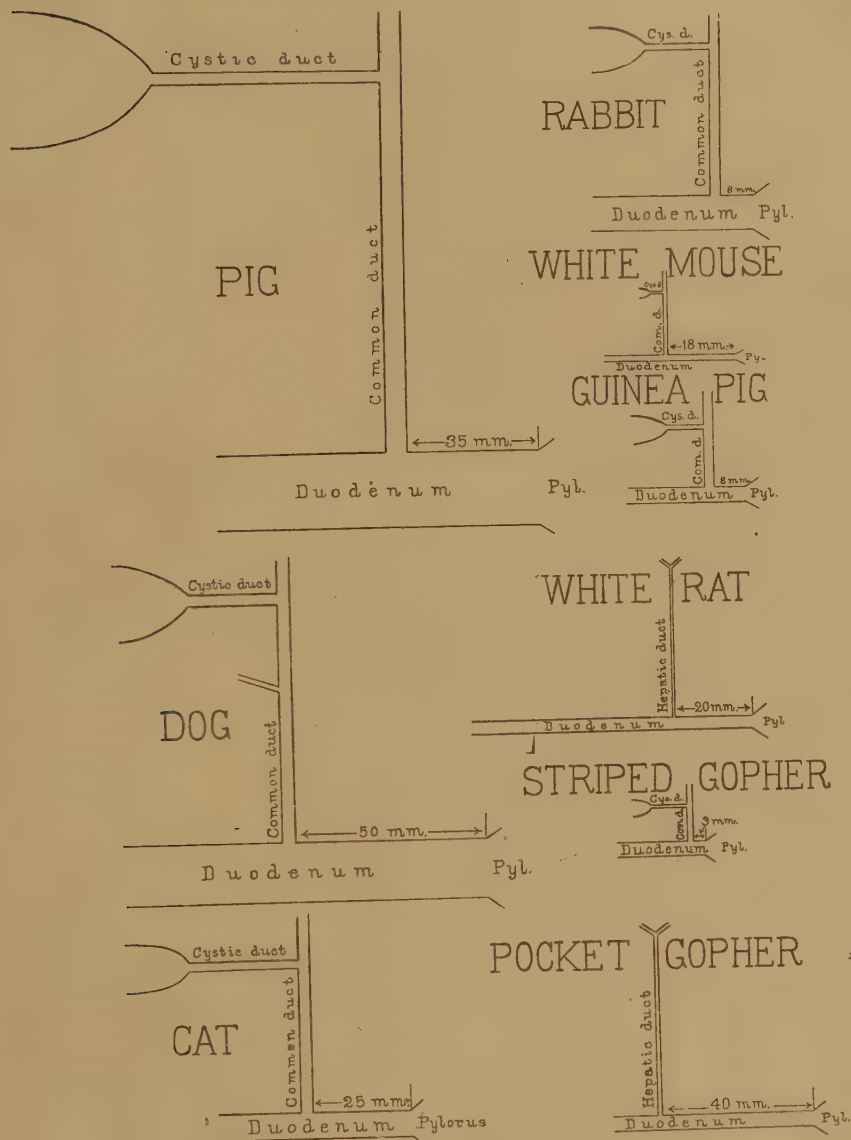


Fig. 17 Diagram showing the exact size and relations of the biliary tract in nine species, two of which (rat and pocket gopher) do not possess a gall-bladder. Note that there is no relation between the size of the ducts and the relation of the entrance into the duodenum in the species with a gall-bladder as compared to those without one.

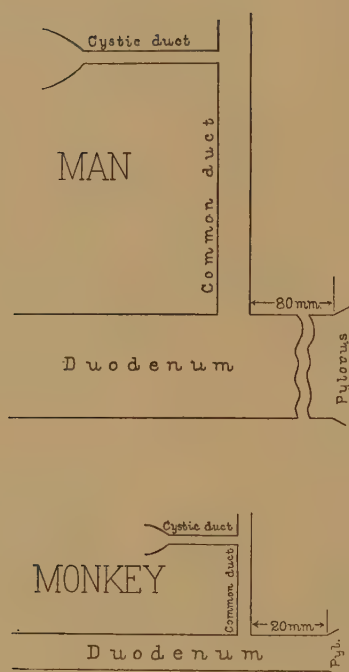


Fig. 18 Diagram showing the exact size and relationship of the biliary tract in man and monkey (*M. rhesus*).

Resumen por G. Carl Huber, por el autor E. V. Cowdry.

La Anatomía en el Japón.

La presente memoria sobre la Anatomía en el Japón es el resultado del estudio de quince de las principales Escuelas Médicas de dicho país, cuyos laboratorios de Anatomía ha visitado el autor. Los datos incluidos en este trabajo referentes a la edad y preparación exigidas a los estudiantes de Medicina en el Japón, el cuadro general de estudios y los cursos de Anatomía en particular, fueron obtenidos de los profesores de Anatomía y de las memorias presentadas al ministro de Educación. Se incluye en el presente trabajo una lista del personal de varios de los departamentos de Anatomía de las escuelas médicas japonesas así como una breve descripción de los laboratorios visitados y de las facilidades de trabajo encontradas. También se incluye una discusión sobre la literatura médica japonesa y una lista muy completa de las revistas médicas publicadas en el Japón. La productividad de los investigadores japoneses en el terreno anatómico y las contribuciones especiales de los anatómicos de dicho país se discuten con detalle.

Translation by José F. Nonidez
Carnegie Institution of Washington

ANATOMY IN JAPAN¹

E. V. COWDRY

*Anatomical Laboratory of the Peking Union Medical College of the Rockefeller
Foundation*

FOUR FIGURES

This report is based upon a personal study of fifteen of the principal Japanese medical schools, supplemented by a careful examination of documents and papers relating to medical education in Japan. It is a pleasure to acknowledge my indebtedness to Professors K. Kunitomo, T. Saito and Y. Suzuki for valuable letters of introduction; and especially to Dr. E. T. Hsieh for help in translation, without which it would have been quite impossible to gather data with any degree of accuracy. Wherever I went I was received with the greatest kindness and courtesy and was given every opportunity for carrying on my investigations. For convenience in description, the medical schools, with the personnel of the anatomical laboratories, may be classified as follows:

MEDICAL SCHOOLS

Imperial University Medical Colleges

1. Hokkaido Imperial University Medical College, Hakodate (It is planned to begin instruction in 1921).
2. *Kyoto Imperial University Medical College, Kyoto.
Professor B. Suzuki
Professor B. Adachi
Professor K. Kamon
Assistant Professor C. Ogawa
Assistant Professor S. Funaoka
3 Assistants

¹ Contributions from the Anatomical Laboratory, Peking Union Medical College No. 3.

* Personally visited.

3. *Kyushu Imperial University Medical College, Fukuoka.
Professor R. Oyama
Professor T. Sakarai
Professor T. Shindo
3 Assistants
4. Tohoku Imperial University Medical College, Sendai.
Professor G. Fuse
Professor N. Nishi
Professor K. Hasebe (?)
Assistant Professor J. Shikinami
1 Assistant
5. *Tokyo Imperial University Medical College, Tokyo.
Professor Y. Koganei
Professor G. Osawa
Assistant Professor R. Futamura
Assistant Professor M. Inouye
Assistants

War Department Medical Colleges (for medical graduates only)

6. Naval Medical College, Tokyo.
7. Army Medical College, Tokyo.

Government Special Medical Schools

8. Chiba Special Medical School, Chiba.
Professor S. Taguchi
Assistants
9. Kanazawa Special Medical School, Kanazawa.
Professor J. Kaneko
Professor S. Saguchi
2 Assistants
10. *Nagasaki Special Medical School, Nagasaki.
Professor K. Kunitomo
Professor M. Hara
3 Assistants
11. Niigata Special Medical School, Niigata.
Professor T. Kudo
Professor K. Koike
Assistant Professor
Assistants

12. Okayama Special Medical School, Okayama.
Professor K. Kosaka
Professor K. Yagita
2 Assistants

Government Medical Schools of lower standard

13. *Keijo Medical School, Seoul, Korea.
Professor T. Kubo
Assistants
14. Taiwan Medical School, Tansui, Formosa.
Professor S. Adachi
1 Assistant

Municipal Medical Schools

15. *Kyoto Prefectural Medical School, Kyoto.
Professor K. Shimada
Professor S. Okasa
Assistants
16. *Nagoya Prefectural Medical School, Nagoya.
Professor G. Narasaka
Professor T. Asai
Professor K. Sato
Assistants
17. *Osaka Prefectural Medical School, Osaka.
Professor R. Tsukaguchi
Professor K. Ogushi
Professor K. Saito
Assistants

Private Medical Schools

18. *Keio Medical School, Yotsuya, Tokyo.
Professor K. Okajima
Professor N. Yatsu.
Assistant Professor K. Okamoto
2 Assistants
19. Kumamoto Special Medical School, Kumamoto.
Professor S. Kimura
Assistants
20. *Nippon Special Medical School, Tokyo.

21. *Tokyo Charity Hospital Special Medical School, Tokyo.
Professor H. Arai
Professor S. Morita
Assistants
22. *Tokyo Special Medical School, Tokyo.
23. *Tokyo Woman's Special Medical School, Tokyo.
24. *Severance Union Medical College (Japanese charter), Seoul,
Korea.
Professor G. Kano
25. *South Manchuria Railway Medical School, Mukden, South
Manchuria (only semi-private).
Professor K. Shiino
Professor K. Kudo
Assistants

BUILDINGS AND EQUIPMENT

Japanese anatomical laboratories are usually well located in spacious grounds, none of the crowding so evident in our larger cities being apparent. Handsome trees are planted about them (figs. 1 and 2) which add greatly to their appearance. The department of anatomy of the Kyushu Imperial University enjoys a stretch of beautiful sandy sea beach almost at its back door, and the Nagasaki Special Medical School is built on the shoulder of a fine mountain which serves as an excellent collecting ground for certain kinds of material and allows of almost unlimited expansion. These large grounds are a distinct asset because they make it possible to keep experimental animals in the open and to erect small buildings for special purposes. A separate building is often reserved for dissection, which is a desirable arrangement from every point of view.

The laboratories present a simple and dignified appearance adapted for use rather than for ornament. The department of anatomy of the Tokyo Imperial University (fig. 1) is housed in a fine semi-fireproof two story brick structure, with separate annexes for histology and gross anatomy, completed in 1906. It is one of the most elaborate of all the institutions visited. The



Fig. 1 Kyoto Imperial University Anatomical Laboratory

Fig. 2 Tokyo Imperial University Anatomical Laboratory

Kyoto Imperial University (fig. 2) ranks next. The smaller colleges exhibit a striking similarity in appearance and are usually built of wood. The photographs of the Nagoya Prefectural Medical School (figs. 3 and 4) are characteristic and show a simplicity which is not devoid of charm.

On the whole the buildings are rather cheaply constructed without regard to permanency and seem rather bare to foreigners who are accustomed to the comforts of central heating and ventilation. The use of wood as the chief building material increases the danger of fire from stoves in the winter time, as shown by the recent fire in the Osaka Special Medical College. The installation of electric light is rather defective. In some of the students' laboratories an attempt is made to get along without any means of artificial illumination.

The rooms and halls are invariably spotlessly clean, and visitors must either take off their shoes before entering the building, and walk around in their stocking feet, or else make use of slippers which are often provided for the purpose.

The dissecting rooms are large and airy and are always fitted with water proof concrete floors and good drainage. They have the appearance of being carefully washed out at least once a day. Skylights are often provided, giving excellent illumination. No hardship is experienced through the lack of forced draught ventilating systems because good use is made of the large and numerous windows.

Material for dissection is plentiful. According to the report of the Minister of Education, 433 bodies were dissected in 1913 at the Kyoto Imperial University. The supply, as one might expect, is government controlled. The bodies come from the prisons, work houses, old people's homes, the University Hospital and other places. An excellent opportunity is thus afforded for the study of physical anthropology of which the Japanese have not been slow to avail themselves. In the storage of bodies chief reliance is placed in sanitary and well-constructed tanks. Refrigeration is seldom resorted to except for the purpose of cutting sections.



Fig. 3 Nagoya Prefectural Medical School. Dissecting room on the left with skylight, and histological laboratory on the right with large windows and shade. The covered passage-way leads to the anatomical museum and private laboratories of the staff.

Fig. 4 Nagoya Prefectural Medical School. Professor's private laboratory.

An interesting arrangement is found in the histological laboratories where the second row of students from the window are quite frequently placed upon a raised platform so that they may conveniently look over the heads of those in front of them and thus secure good illumination for microscopic work.

The equipment in all the colleges visited, with the single exception of the Woman's Medical College, is up-to-date in every particular, and is often lavish in amount. German microscopes predominate, and Japanese firms are now making excellent imitations of Jung sliding microtomes and other important pieces of apparatus.

I had the pleasure of visiting some most creditable museums. The Tokyo and Kyoto Imperial Universities possess valuable collections of anthropological material which bear testimony to the industry of Professors Koganei and Adachi respectively. The former is famous for its unique assortment of Ainu skeletons. An active anthropological institute is attached to the Tokyo Imperial University in which may be found a well arranged collection of ethnological and archeological specimens. Comparative types are well represented in the museum at Fukuoka. Each college has a carefully kept collection of larger or smaller size, special attention being paid to models of embryos and dissections, which the Japanese make very skillfully.

The medical libraries are usually divided between the different departments. An overwhelming majority of the books and journals are German. American periodicals, with the exception of those published by The Wistar Institute, are conspicuous by their absence. Special attention is not given to displaying the current numbers of the journals where they may be easily seen.

STAFF

The personnel of the anatomical laboratories is made up for the most part of men who have been trained in Germany. In fact visitors who are unfamiliar with Japanese are often obliged to speak German in order to make themselves understood. This handicap is being gradually overcome through the influence of

the younger men who have studied in England and America. Instructors freely acknowledge that they have been temporarily forced to use English textbooks, because the supply of second hand German ones has been completely exhausted.

TABLE 1
Anatomical staff

COLLEGE	PROFESSORS	ASSOCIATE PROFESSORS	ASSISTANT PROFESSORS	LECTURERS	ASSOCIATES	INSTRUCTORS	ASSISTANTS	TEACHING FELLOWS	TOTAL STAFF	STUDENTS IN FIRST YEAR	RATIO OF TEACHERS TO STUDENTS
Kyoto Imperial University, 1917-18.....	3		2				3		8	81	1: 10.1
Kyushu Imperial University, 1917-18.....	1		2				3		6	68	1: 11.3
Tohoku Imperial University, 1918-19.....	2		2				1		5	47	1: 9.4
Nagasaki Special Medical School, 1918-19.....	2						3		5	105	1: 21
Kanazawa Special Medical School, 1918-19.....	2						2		4	125	1: 31.2
Okayama Special Medical School, 1918-19.....	2						2		4	126	1: 31.5
South Manchuria Railway Medical School, 1918-19.....	2						2		4	50	1: 12.5
University of Chicago, 1918-19....	4		3	2	2	2			13	67	1: 5.1
Cornell University (Ithaca and New York), 1917.....	2		1			1	4		8	63	1: 7.8
Columbia University, 1918-19....	1		2	2		5	1		11	213	1: 19.3
University of California, 1918-19..	1	1	2			1	3		7	63	1: 9
North-Western University, 1918-19	1	1				2			4	59	1: 14.7
Yale University, 1918-19.....	1		1			2			4	22	1: 5.5
Harvard University, 1917-18.....		4				4	6	1	15	94	1: 6.2

In comparison with American standards, the staff is very limited in number in consideration of the very arduous duties which they have to perform. It will be seen from table 1 that in seven representative Japanese Universities there is an average of one teacher in anatomy for every eighteen students (1:18.1)

while in American institutions of similar grade one teacher is provided for every nine students (1:9.5). This would not be significant were it not for the fact that teaching is made difficult for the Japanese. The buildings are often too small for the classes, which have to be divided into sections, so that the instructors are obliged to double their working hours by teaching the same subject twice. This condition of affairs is of course not unknown in the United States, but I am firmly convinced that it is of much rarer occurrence than in Japan. The hardest burden which the Japanese have to carry is their lectures, which usually occupy over 50 per cent of all the time set apart for anatomy (table 5). In the general course at the Keijo Medical School they actually consume 90 per cent of the time. The additional strain of conducting a course in gross anatomy, for example, in which more time is given to lectures than to dissection is obvious. Moreover, the Japanese authorities, in my opinion, do not regard the students as grown men who are responsible for their own careers, with the result that they spend a great deal of valuable time in what is commonly called 'spoon-feeding.' Military discipline prevails throughout the medical course, especially in the government institutions, so that there is little opportunity for the development in the students of individual initiative.

According to Imperial Ordinance No. 210 the professors in the Tokyo Imperial University shall be of *chokunin* or *sonin* rank, the assistant professors of *sonin* rank and the assistants of *hannin* rank. These titles are explained in the report of the Minister of Education as follows:

Officials of the rank of *chokunin* are those appointed either by His Majesty the Emperor in person or by His order.

Officials of the rank of *sonin* are those appointed by the Minister President of State with the approval of His Majesty the Emperor.

Officials of the rank of *hannin* are those appointed by the heads of the Government Departments.

All helpers of lower grade are called *yatoi* or *shokutaku* and are unrecognized officially.

Ordinance No. 211 applies to Kyoto and it is likely that a similar regulation is in force in all the Imperial Universities. I have been unable to secure data bearing upon appointments in the government special medical schools and private institutions.

The terms and duration of appointments, salary, and other particulars are, so far as I have been able to determine, not published. They are not mentioned in the reports of the Minister of Education. One would expect promotion to be fairly rapid in a progressive country like Japan with new medical schools springing up almost over night. Equilibrium has not yet been established, and there are certainly more positions than there are highly trained men to fill them.

The majority of the teachers are on a full time basis, as in the United States; but the assistants are so poorly paid that it is often necessary for them to supplement their income by teaching in other schools when the opportunity offers. I am told, for instance, that in Tokyo the assistants in anatomy of the Imperial University give instruction in the Nippon Medical School, perhaps also in the Tokyo Medical School. The professors, on the other hand, have proportionally very much larger salaries and live fairly comfortably.

Quite frequently the assistants receive no remuneration whatever as indicated by the somewhat ambiguous statement: "Unpaid assistants are appointed in the institutes, laboratories, workshops, and hospitals, attached to the several colleges, and under certain circumstances allowances may be specially paid to them."

To place all this routine work on the shoulders of the rising generation does not make for progress. The older men should relieve the younger ones and help them to make their way in the world, realizing full well that these younger men have it in them to develop and to be a credit to the nation. Moreover, the best results will come when the men of experience do the greater part of the teaching.

TEACHING

The students present a very military appearance in well-fitting uniforms which they are obliged to wear in most of the private schools as well as in the government institutions. One cannot help being pleased by their courtesy to strangers and by the deference with which they treat their instructors. The health of the students is carefully guarded by the authorities. Keio University makes a special point of even surpassing the Government Institutions in this respect.

According to table 2, which I have compiled from the Forty-first report of the Minister of Education to the Emperor, it will

TABLE 2
Average age of entering medical students

COLLEGE	1909		1910		1911		1912		1913	
	Years	Months	Years	Months	Years	Months	Years	Months	Years	Months
Tokyo Imperial University.....					23	8	23	3	23	9
Kyoto Imperial University.....					24	10	24	11	24	11
Tohoku Imperial University.....	21	5	21	5	20	9	20	4	20	9
Kyushu Imperial University.....					24	0	24	0	24	0
Government Special Schools of Medicine....	20	10	19	10	20	6	20	7	20	6

be seen that the entering students are rather older than one would expect. At the Kyoto Imperial University they are on an average nearly twenty-five years old and must therefore be fairly mature before they begin their medical education. Some doubt is cast upon the accuracy of the figures, in the case of the Tokyo Imperial University, by the fact that the Calendar for the year 1917-1918 does not agree with the Minister's report.

Unfortunately I did not have an opportunity to investigate entrance requirements in detail. They are highest in the case of the Imperial Universities and consist of three years pre-medical work after graduation from the middle schools. In the government special schools and municipal medical schools only two years are required. The requirements for admission to the

private medical schools vary. In some they are undoubtedly very meagre, while in others, like the Keio Medical School, they are probably as exacting as those of the Imperial Universities. Presumably these several years of preparatory work are of college grade. The Imperial Universities and the Special Medical Schools at Chiba, Okayama, Kanazawa, Nagasaki and Niigata are under the direct control of the Department of Education so that much valuable information may be obtained from the Minister's report. We are told that admittances were granted to the Imperial Universities according to table 3.

Discounting the 711 applications for admission in the case of the Tohoku Imperial University, which would appear to be a typographical error, we find that surprisingly few candidates fail

TABLE 3
Admittance of medical students, 1913-1914

COLLEGE	APPLIED FOR ADMITTANCE	PASSED
Tohoku Imperial University.....	711	131
Kyoto Imperial University.....	89	89
Kyushu Imperial University.....	107	107
Tokyo Imperial University.....	146	142

to measure up to the requirements. In Kyoto and Kyushu, for example, all those who applied for admittance were allowed to enter and only 4, out of a total of 146, failed in the Tokyo Imperial University.²

On page 176 of his report the Minister of Education gives the following information regarding admission to the special medical schools under his control (table 4, page 80).

The first total is questionable because on the preceding page he states that the total for 1913-14 was 655. The figures, how-

² I am indebted to Mr. Roger S. Greene for the suggestion that the remarkably small number of failures may be explained by the fact the prospective students have to pass very exacting examinations before they leave the preparatory schools, so that the real test comes before they make application for entrance to the universities.

ever, show that only a very few students enter who are not graduates of the middle schools.

The difficulty of gathering accurate information is even greater in the case of the medical schools not under the Department of Education. I have often received verbal confirmation of the statement made in the report of the China Medical Commission of the Rockefeller Foundation that the entrance requirements are reduced in the case of Chinese students. There is a widespread feeling that Chinese students are unfairly treated during the medical course. It is said, for instance, that they are not allowed the same amount of time for study as the Japanese. I have not had sufficient experience to either confirm or deny this statement. Neither have I been able to discover whether any

TABLE 4

Qualifications of entering students

YEAR	GRADUATES OF MIDDLE SCHOOLS	PASSED TEST EXAMINATION	TOTAL
1913-14	616	5	621
1912-13	607	4	611
1911-12	703	20	723
1910-11	708	4	712
1909-10	653	2	655

discrimination is exercised against non-Japanese students in Manchuria or Formosa.

Through the kindness of the authorities I was permitted to make a careful study of the medical school maintained by the Japanese Government at Seoul, in spite of the fact that some of the buildings were occupied by troops in connection with the disturbances arising from the independence movement. The school is well equipped, but the Koreans are given a different course of instruction from the Japanese. They take the so-called "general course" (table 5), which is woefully inadequate, only 36 hours being devoted to dissection. A 'special course' is provided for the Japanese. Detailed information is given in the regular announcement of the school.

The Minister of Education has issued an order giving the minimum requirements for work in the Government Special Medical Schools which I have had translated from the 1918 catalogue of the Okayama Special Medical College and rearranged so that it may be easily compared with the recommendations of the Association of American Medical Colleges. In the original only the number of hours work per week are given. The totals in my list have been calculated on the supposition that the course is intended to extend over 36 weeks in each year, as is customary in Japan. Unfortunately the division of the allotted time between lectures and laboratory work is seldom specified.

Minimum curriculum for government special Medical Schools compiled from an order issued by the Japanese Minister of Education, 1916

1. German.....	720 hours	16.4 per cent
2. Military drill.....	98 "	2.2 " "
3. Moral lessons.....	144 "	3.2 " "

Division 1. Anatomy, 684 hours, 15.6 per cent

	<i>Total Hours</i>	<i>Lecture</i>	<i>Laboratory</i>
<i>a</i> Gross anatomy.....	432	288	144
<i>b</i> Regional anatomy.....	36	36	
<i>c</i> Histology.....	180	72	108
<i>d</i> Embryology.....	36	36	

Division 2. Physiology and chemistry, 576 hours, 13.1 per cent

<i>a</i> Chemistry.....	216	....	....
<i>b</i> Physiological chemistry.....	126	....	....
<i>c</i> Physisology.....	234	....	....

Division 3. Pathology, bacteriology and hygiene, 504 hours,
11.2 per cent

<i>a</i> Bacteriology.....	144	....	....
<i>b</i> Hygiene.....	144	....	....
<i>c</i> Theory of pathology.....	216	216	....
<i>d</i> Gross pathology.....		occasionally	
<i>e</i> Laboratory pathology.....	72	72	....

Division 4. Materia medica and therapeutics, 126 hours,
2.8 per cent

<i>a</i> Materia medica.....	108	....	....
<i>b</i> Therapeutics.....	18	....	....

Division 5. Medicine and medical specialties, 520 hours,
11.8 per cent

<i>a</i>	Theory of medicine.....	216	216	....
<i>b</i>	Bedside instruction.....	216	....	216
<i>c</i>	Diagnosis.....	72	72	....
<i>d</i>	Venereal diseases and dermatology.....	16	....	....
<i>e</i>	Out-patient clinics.....	no required time		

Division 6. Surgery and surgical specialties, 828 hours,
18.9 percent

<i>a</i>	General surgery.....	108	108	....
<i>b</i>	Special surgery.....	108	108	....
<i>c</i>	Bedside instruction.....	288	....	288
<i>d</i>	Out-patient clinics.....	no required time		
<i>e</i>	Bandaging.....	36	....	36
<i>f</i>	Operative technique.....	36	....	....
<i>g</i>	Eye.....	216	....	....
<i>h</i>	Ear, nose and throat.....	36	....	....

Division 7. Obstetrics and gynecology, 180 hours, 4.1 per cent

<i>a</i>	Obstetrics.....	108	108	....
<i>b</i>	Gynecology (including some abdominal surgery).....	72	72	....
Total hours.....		4380		

It is interesting to observe: 1) the large amount of time devoted to the study of German; 2) the high percentage of lectures in anatomy and pathology; 3) the failure to provide for practical work in pharmacology, and 4) the relatively large amount of time set apart for ophthalmology, as compared with otology, rhinology and laryngology.

As a matter of fact the courses given are a good deal heavier than this order calls for. They amount in all to nearly 5000 hours crowded into a period of four years. A rather smaller percentage of the time is devoted to anatomy than in our own institutions. In Japan it amounts, in practise, to about 13 per cent, while the Association of American Medical Colleges recommends 18 per cent. In his report on Medical Education in the United States and Canada, Flexner writes that: "Something like one-fifth of the available time of the entire medical curriculum is commonly absorbed by the various branches constituting a

modern department of anatomy." Detailed information respecting typical Japanese medical schools is given in table 5. The data presented has been obtained from translations of the official announcements of the different colleges. A few errors have undoubtedly crept in in connection with special holidays and other variables but no effort has been spared to reduce them to a minimum.

Gross anatomy usually extends through the first two years, Keioh University being an exception, and we note at once that fully half of the student's time is occupied by listening to lectures. According to our western standards this is a deplorable state of affairs. The whole medical curriculum rests on the science of anatomy and it is essential that the students should have a very practical first hand knowledge of the structure of the human body, as well as thorough training in the art of dissection, if they are to become good physicians and surgeons. It seems to be a well established custom for the lectures to precede the laboratory work. In the Tokyo Imperial University (1917-1918) the students must listen to about one hundred and eighty lectures before they are allowed to undertake any dissection. They accordingly come to the laboratory with strongly preconceived ideas and are robbed of the privilege of trying to discover the structure of the human body for themselves. As we journeyed from place to place I was able to detect but little evidence of individual resourcefulness on the part of the instructors in raising the subject above the level of a dull grind. We do not find living models used at one place; X-ray, at another; clay modelling, at a third; and so on. There is a tendency for the students to take what they are given in a purely passive way. Individual initiative is not kindled and encouraged.

In histology there are also many lectures and the laboratory work is proportionally reduced. The course usually extends on into the second year and the students are well lectured before they see the inside of the laboratory. In most of the colleges which I visited the students have an opportunity to stain some sections for themselves by the ordinary methods of technique, but I doubt whether due attention is paid to the study of living

TABLE 5
Anatomical curriculum

COLLEGE	KIND OF WORK	ANATOMY	HISTOLOGY	EMBRYOLOGY	COMPARATIVE ANATOMY	USE OF MICROSCOPE	NEUROLOGY	TOPOGRAPHIC ANATOMY	PERCENTAGE OF LECTURES	TOTAL FOR ANATOMY	TOTAL FOR MEDICAL COURSE	PERCENTAGE OF ANATOMY
Tokyo Imperial University, 1917-18.....	Laboratory	380	91									
	Lecture	324	54	28	28			54	50.09	959		
Kyoto Imperial University, 1911-12.....	Laboratory	324	78									
	Lecture	430	50	55				50	59.2	987		
Kyushu Imperial University, 1917-18	Laboratory	260	72									
	Lecture	312	48	48				48	57.8	788	4992	15.8
Tohoku Imperial University, 1918-19	Laboratory	240	72									
	Lecture	228	24	24				36	50.0	624		
Kanazawa Special Medical School, 1918-19	Laboratory	144	108									
	Lecture	288	72	36				36	63.1	684	4470	15.0
Nagasaki Special Medical School, 1918-19	Laboratory	144	108									
	Lecture	288	72	36				36	63.1	684	4470	15.0
Nagoya Prefectural Medical School, 1918-19	Laboratory	216	180				108					
	Lecture	72	72	36				36	30.0	720		
Okayama Special Medical School, 1918-19	Laboratory	144	72									
	Lecture	288	108	36				36	68.4	684	5500	12.4
South Manchuria Railway Medical School, 1918-19	Laboratory	148	72									
	Lecture	298	48	36				48	66.1	650	5416	12.0

TABLE 5—*Concluded*

COLLEGE	KIND OF WORK	ANATOMY	HISTOLOGY	EMBRYOLOGY	COMPARATIVE ANATOMY	USE OF MICROSCOPE	NEUROLOGY	TOPOGRAPHIC ANATOMY	PERCENTAGE OF LECTURES	TOTAL FOR ANATOMY	TOTAL FOR MEDICAL COURSE	PERCENTAGE OF ANATOMY
Keijo Medical School, 1918-19	(a) Special course Laboratory Lecture	144 340	54 54						66.5	592	4922	12.0
(b) General course	Laboratory Lecture	36 252				72			90.0	360	4448	8.0
Niigata Special Medical School, 1918-19	Laboratory Lecture	145 289	108 72	36				36	63.1	686	4752	14.4
Tokyo Woman's Special Medical School	Laboratory Lecture	144 288	108 72	36				36	63.1	684	4824	14.1
Keioh University	Laboratory Lecture	324 288	101 36	24					45.0	773		

material, though this is very important if they are to acquire a functional conception of all they see.

Judging from the published announcements of the different medical schools, and from my own observations, the course in embryology must be entirely theoretical.³ It is to be hoped that the lectures are regularly supplemented by carefully prepared demonstrations because the outlook of students who have never personally examined living embryos of lower animals, and carefully compared their development with the growth of human embryos, is apt to be restricted.

Courses in comparative anatomy and neurology are seldom announced. Lectures are regularly given in topographical, or

³ The Osaka Prefectural Medical School would seem to be an exception since, in the proposal to place the work on a university basis, 18 hours are set apart for laboratory work in embryology.

applied anatomy, which merely serve to supplement the hundreds already delivered in gross anatomy.

The advantageous position enjoyed by anatomy at the very beginning of the medical curriculum is passed by unnoticed. Japanese students, like their fellows all the world over, enter the medical school quite unspoiled, with acute perceptions and filled with enthusiasm. Their mental development and success in life are, in large measure, conditioned by the treatment which they receive in the first few courses that they take. This great responsibility rests fairly and squarely upon the shoulders of the anatomist, and in order to rise to the occasion and do his duty he must take cognizance of recent advances in the science of pedagogy—on no account must he merely repeat the treatment which he received in his youth. That each reacts in different ways is evidenced by the opinions expressed at the symposium on 'The teaching of Anatomy' held at the thirty-fourth session of the American Association of Anatomists, and it is right that it should be so, because it shows that the instructors are putting their personality into their teaching. The teaching of anatomy has come to be a fine art which must be actively cultivated by those who would keep abreast of the times. It is, perhaps, not too much to say that the courses in anatomy, if skillfully managed, may be made the most interesting as well as the most fundamental of the entire medical curriculum.

Most of the medical schools follow the lead of the Imperial Universities and pattern their examinations after the German ones. The first, including anatomy and the other preclinical subjects, is held at the end of the second year; and the second, devoted to clinical work, comes at the end of the fourth year. In the Tokyo Imperial University there is a by-law which provides that "The examination mark in Anatomy shall be determined by adding twice the mark given for Systematic Anatomy to that for Histology, and by dividing the sum thus obtained by three." It would seem from this that the gross anatomy is thought to be twice as important as the microscopic work. No special provision is made for mitigating the severity of the examination by judging the student on the basis of the quality

of the practical work which he has been doing during his first two years in the medical school.

I have no data bearing on the results of the examinations but by comparing the number of students in the second and third years, that is to say before and after the examination, we can get a rough idea of the number who fail. In seven representative colleges there is an average of 83 students in the second year and 80 in the third. This is quite a healthy condition of affairs, because a high 'mortality' is not necessarily a good thing. Indeed, a large percentage of failures may be taken to indicate either that the entrance requirements are not properly enforced, or else that the teaching is at fault; for obviously if the students are qualified to enter and the teaching is what it should be, we would expect them all to pass their examinations. In the better universities in the United States there are also comparatively few failures.

Flexner states that: "The two striking features of German medical education are the domination of the lecture method and the elasticity of the curriculum." We have seen that the first element has been faithfully reproduced to the complete exclusion of the second; for the Japanese medical curriculum is rigid and inflexible. There are no elective courses worthy of the name. All the courses must be endured and there is but little opportunity for the students to develop character and self reliance. The instructors are overworked and have neither the time nor the energy to encourage the more promising students to specialize along lines which interest them. Many good investigators are thus lost to science on account of the lack of favorable conditions for the development of their talents.

There is a strong movement in the United States in favor of condensation of effort which has not yet influenced medical education in Japan. The students are considered to be mature so that it is unnecessary to shift rapidly from one subject to another in order to hold their interest and prevent their capacity for assimilation from being over strained. Quoting again from Flexner: "The first few months of the medical curriculum are then given over to anatomy alone; for it is clearly illogical to

begin even physiology till the anatomist has made some headway. Concentration is economical of time and energy and stimulates the student to push on beyond definitely prescribed limits." Professor Mall was a great exponent of this method.

The admission of women students on the same terms as men is another advance in medical education in which the Japanese have not participated. The Woman's Special Medical College in Tokyo is the only place where they are permitted to work. This pioneer organization deserves the greatest credit for the courage with which it struggles on in the face of stubborn opposition and prejudice. It is financed by private contributions and is much in need of funds so that the buildings are inadequate and the scientific apparatus negligible. The grounds border on a public cemetery and are far from inviting. The students appear to be bright and intelligent but they are not provided with as good equipment for their work as the Koreans. When I enquired after the opportunities for practise enjoyed by the graduates I was told that "they do very well in Burma, where many of them go." It is to be hoped that their successors will have an easier road to travel and that they will receive the recognition at home which they merit.

The statistics given in the announcements of the medical schools and in the reports of the Minister of Education with regard to the subsequent careers of men and women graduates are not kept in sufficient detail to allow us to draw conclusions as to the actual results of medical education in Japan, but with slight changes the outlook is very promising.

RESEARCH

A great many more highly creditable original investigations are being carried on in anatomy, under these rather unfavorable conditions, than one can see at first sight.

The absence of a special journal devoted exclusively to the publication of research work in anatomy is very keenly felt. Under the present arrangement the various papers are widely distributed through different medical journals so that it is by

no means easy to appraise them fairly. The language difficulty is being gradually overcome through the printing of papers in English or German and the addition of foreign summaries to the Japanese texts. Even the best Japanese journals are not properly represented in our libraries so that some of our investigators are actually ignorant of their existence. This must be corrected unless we are willing to run the risk of devoting years of our lives to the solution of problems which have already been solved through the skill and ingenuity of Japanese investigators.

Useful abstracts of many of the current Japanese journals are made by the Research Staff of the Severance Union Medical College, under the direction of Dr. Ralph R. Mills, and are published in the *China Medical Journal*. The *Index Medicus* only lists a few of the more important journals. Unfortunately there is no publication in any foreign language in which we can find complete reviews of Japanese medical literature. The following list of journals may not be complete or correct, but it serves to illustrate the duplication in subject matter.

JAPANESE JOURNALS

Acta Scholae Medicinalis Universitatis Imperialis in Kyoto (mostly in German).

Arbeiten aus dem Anatomischen Institut der Kaiserlichen Universität zu Sendai (printed chiefly in German).

Central Journal of Medical Science, Tokyo (Japanese only).

Chiba-Igakusenmongakko-Zasshi, Chiba Medical College, Chiba (Japanese with German abstracts).

Chosen Medical Society Journal (*Chosen Igakukai Zasshi*).

Clinical Medicine, every 10 days, 8 Kiridosht, Sakamachi, Hongo, Tokyo (Japanese with German abstracts).

Daily New Medical Science, 6 Fuchi, section 9, Tokyo (Japanese only).

Formosa Medical Society Journal (*Taiwan Igakukai Zasshi*), Government Medical School, Formosa (Japanese only).

Fukuoka Medical College Journal, Journal Department Kyoto Imperial University, Kyoto (Japanese only).

Japanese and Foreign Medical News (*Chugai Iji Shimpō*), Nos. 1-17, The Japanese and Foreign Medical News Publisher, Tokyo (Japanese with abstracts in English, French or German).

Japanese Journal of Cancer Research (*Gann*), quarterly, Dr. Mataro Nagayo, Tokyo Imperial University, Tokyo (printed in Japanese with abstracts in English or German).

- Japanese Medical Reviews* (*Nippon-no-ikai*) (Japanese only).
- Japanese Medical Weekly*, Nankodo, 8 Kiridoshi, Sakamachi, Hongo, Tokyo.
- Japanese Medical World*, Nankodo, 8 Kiridoshi, Sakamachi, Hongo, Tokyo (Japanese with English or German abstracts).
- Japanese Protozoological Association Journal*, Department of Protozoology, Imperial University, Tokyo.
- Japanische Zeitschrift für Dermatologie und Urologie* (*Hifukwa, Hitsunyokwa Zasshi*), vols. 1-17, Dermatological Association of Japan (Japanese with German abstracts).
- Journal of Bacteriology* (*Saikingaku Zasshi*), Nos. 1-269, Kitasato Institute, Tokyo (Japanese with English or German abstracts).
- Journal of the Central Medical Association*, (*Chuo Igakkai Zasshi*), Tokyo (Japanese only).
- Journal of the College of Science of the Tokyo Imperial University* (almost all the papers are printed in English).
- Journal of Japanese Ophthalmological Association* (*Nippon Gankwa-gakkai Zasshi*), Department of Ophthalmology, Imperial University, Tokyo (Japanese with foreign abstracts).
- Journal of Japanese Society of Internal Medicine*, every 10 days, Nankodo, 8 Kiridoshi, Sakamachi, Hongo, Tokyo (Japanese only).
- Journal of Military Surgery of Japan*, *Gunidau Zasshi*, Nos. 1-74 (Japanese with German abstracts).
- Journal of Pediatrics* (*Jikwa Zasshi*) The Pediatrics society, Tokyo (Japanese only).
- Journal of the Perfection Medical Society* (*Juzenkai Zasshi*), Kanazawa Medical College, Kanazawa (Japanese only).
- Kitasato Archives of Experimental Medicine*, vols. 1-2, Kitasato Institute, Tokyo (printed in English).
- Kyoto Journal of Medicine and Sanitation*, Kyoto Iji Eisei Shi, Nos. 1-285, No. 89, 2nd St., Kyoto, Japan (Japanese with occasional abstracts).
- Kyoto Medical Journal* (*Kyoto Igaku Zasshi*), vols. 1-15 Kyoto Imperial University, Kyoto (Japanese with English abstracts).
- Manchuria Medical Journal*, South Manchuria Railway Medical School, Mukden, Manchuria (Japanese only).
- Medical News* (*Iji Shimbun*), Nos. 1 to about 990, The Medical News Publisher, Tokyo (Japanese only).
- Medicine and Politics*, weekly, Nankodo, 8 Kiridoshi, Sakamachi, Hongo, Tokyo (Japanese only).
- Mitteilungen aus der medizinischen Gesellschaft zu Tokyo*, Tokyo Igakukai Zasshi (Japanese with German or English abstracts), vols. 1-33.
- Mitteilungen aus der medizinischen Hochschule zu Keijo*, 1917 to date (printed in German and English).
- Mitteilungen aus der Japanischen medizinischen Hochschule zu Mukden*. 1916 to date (papers printed English, German and Japanese).
- Mitteilungen aus der medizinischen Fakultät der Kaiserlichen Universität zu Tokyo* (chiefly in German).

- Modern Medicine*, Tokyo (Japanese only).
Modern Therapy, Nankodo, 8 Kiridoshi, Sakamachi, Hongo, Tokyo (Japanese with German abstracts).
Okayama Medical Society Journal, Mr. K. Matsuda No. 18, Kuyama-cho, Okayama city (in Japanese with German abstracts).
Sei-i-kwai Medical Journal, Tokyo Charity Hospital Medical College (some papers printed in English and others in Japanese).
Tokyoer Medizinische Wochenschrift, Tokyo (Japanese with German abstracts).
Tokyo Medical Association Journal, Department of Physiology, Imperial University, Tokyo (Japanese with English or German abstracts).
Tokyo Medical News (Tokyo Iji Shinshi), Nos. 1-2060 (Japanese with English or German abstracts).
Zeitschrift für Oto-Rhino- und Laryngologie, Department of Ear, Nose and Throat, Imperial University, Tokyo.

The result is that librarians are bewildered and hesitate to subscribe to any of the journals because they find it difficult to determine which are the best. If each important branch of medicine were represented by a first class journal, costing say 25 or 30 yen per annum, published in some foreign language (English, French or German) it would force its way irresistibly into all the great libraries of the world and Japanese medicine would at once receive international recognition. In order to realize this ideal some journals will have to be discontinued, others strengthened and new ones created. This can best be done by the energetic action of the investigators themselves with the support of the Government, the publishers, the lithographers and others. The Emperor himself might well take a personal interest in such an important question. The publication of the "Kitasato Archives of Experimental Medicine" is a move in the right direction and we must not forget that the Japanese realized the need for a journal devoted exclusively to investigations in cancer and began publishing 'Gann' in 1907, nine years before the American Journal of Cancer Research was founded. It is highly desirable that the journals should be supported by vigorous societies in the medical and surgical specialties. Anatomy is particularly fortunate in this respect.

The Tokyo Anthropological Society was founded in 1884, chiefly through the efforts of the late Professor Tsuboi, and

numbers now nearly three hundred members many of whom are anatomists. Meetings are held monthly, except during July and August, at the Anthropological Institute of the Tokyo Imperial University. Professor Torii usually takes charge of the ethnology, Professor Ishii of the general anthropology, while physical anthropology is well represented by Professors Koganei, Hasebe, Adachi and others. The proceedings of the society are published every month in Japanese.

It is highly desirable that no efforts should be spared to bind anthropology closely to the parent science of anatomy. This is the logical condition of affairs and has been fully realized in Great Britain where the most eminent anthropologists are primarily anatomists. The danger of a marked line of cleavage between anatomy and anthropology as illustrated by the present status of anthropology in the United States as described by Boas, Hrdlička and Tozzer in a recent report to the National Research Council.

The Japanese Association of Anatomists is a more recent development.⁴ Meetings are held yearly in the month of July at different laboratories throughout the Empire. At the last meeting the following papers were read:

JAPANESE ASSOCIATION OF ANATOMISTS

Tokyo, July, 1919

President: Professor R. Koganei, Tokyo Imperial University.

Secretary-Treasurer: Professor M. Inouye, Tokyo Imperial University.

1. The surface of the monkey's brain. K. Shimada, Kyoto Prefectural Medical School.
2. A morphological study of the symphysis pubis in man. S. Sasaki, Kyoto Imperial University.

⁴At the time of writing there are but fifty-four members, who are almost without exception professional anatomists of experience. It is apparently irregular for younger men of the rank of assistant to join the association. Persons engaged in the investigation of closely allied sciences like zoology, physiology, pathology and surgery are conspicuous by their absence. On the whole, I cannot help feeling that it would be highly desirable to greatly expand the activities of the association by reducing the requirements for admission to those originally in force for the American Association of Anatomists (*Anat. Rec.*, 1919, vol. 16, p. 132).

3. The development of the placenta of the mouse. J. Oh-hashì, Nagoya Prefectural Medical School.
4. The distribution of sensory nerves in the legs of Japanese. J. Oh-hashì, Nagoya Prefectural Medical School.
5. The secreting-graunla of the pancrease cells of the dog. K. Takagi, Osaka Prefectural Medical College.
6. Electrolytic investigation of the blood corpuscles of dogs. M. Seki, Okayama Special Medical School.
7. The external form of the human kidney. S. Adachi, Taiwan Medical School.
8. The absorption of sunlight by animal tissues. S. Funaoka, Kyoto Imperial University.
9. The brain weight of criminals. M. Hara, Nagasaki Special Medical Schools.
10. Determination of the centers of origin of the splanchnic nerves by a new experiment. K. Yagita, Okayama Special Medical School.
11. The regeneration of the lens of the eye. M. Ogawa, Kyoto Imperial University.
12. The cleavage and metamorphosis of frog larvae. K. Sato, Nagoya Prefectural Medical School.
13. The development of the primitive elements of the lungs of bird embryos. J. Sikinami, Tohoku Imperial University.
14. The structure of the thyreoid gland of the chick. S. Kimura, Kamamoto Special Medical School.
15. The development and reduction of the tail and of the caudal end of the spinal cord. K. Kunitomo, Nagasaki Special Medical School.
16. The anatomy of the mutilated feet of Chinese women. K. Syno, South Manchuria Railway Medical School.
17. The connection between smooth muscle fibers of mammals. J. Okaza, Kyoto Prefectural Medical School.
18. The staining of elastic fibers with Weigert's haematoxylin. J. Okaza, Kyoto Prefectural Medical School.
19. Demonstrations of the human liver, etc., B. Suzuki, Kyoto Imperial University.
20. Demonstration. K. Kamon, Kyoto Imperial University.
21. A fine threadlike substance in the liver cells of frog larvae. Y. Nagamatzu, Nagoya Prefectural Medical School.
22. The outline of the insertion of muscles in bone. K. Okajima, Keioh Medical School.
23. The gustatory nerve. R. Futamura, Tokyo Imperial University.

Active original investigation is being carried on in all branches of anatomy. Kiyono and his associates are doing good work in the study of vital stains. Mitochondria are being investigated by Saguchi and others. Morphology and neurology, compara-

tive anatomy and embryology are well patronized, but I look in vain for references to work along the lines of tissue culture and micro-dissection. Up to the present the Japanese have not opened up any special lines of work in anatomy of their own initiative, but the fact that they have already accomplished so much is greatly to their credit. We cannot, in reason, expect them to reveal simultaneously their capacities in all branches of science.

Special provision is made in the Imperial Universities for students who wish to make a beginning in research. They are allowed to enter the so-called 'University Halls' for a fixed period of two years which may be prolonged at the discretion of the President. A limited number of scholarships are provided in order to help the students financially. No research appointments or professorships are available for advanced investigators in anatomy or allied subjects.

Excellent facilities are also provided for research work at the Marine Biological Station of the Tokyo Imperial University, at Misaki, during the summer vacation. The Tohoku Imperial University also maintains a well equipped Marine Laboratory at Oshoro, in the north, where investigators are welcome.

The value of foreign travel is thoroughly appreciated by the Japanese Government and a good deal of money is spent in making it possible for the best students to work in scientific laboratories the world over. When this policy was first introduced the Japanese at home naturally assumed that the foreign medical schools were fairly uniform in standard, like their own, and placed a premium on foreign degrees in general with the result that the students patronized the poorer schools where the degrees could be most easily obtained. Fortunately this misconception has been corrected, in the eyes of the medical profession at any rate, by the report of the Japanese Commission on Education. Rather too much emphasis is still placed upon the desirability of completing a definite piece of research work during the period of foreign study; because undue pressure is likely to have a detrimental influence upon the quality of the work.

In order that the country may reap the full benefits from this expenditure for foreign travel, the returning students, flushed with enthusiasm, should be received with kindly sympathy by the older men, even when their ideas seem at first sight to be a little radical. Their counsel should be actively sought in matters of medical education and research. They should be given every opportunity to continue their studies, unburdened by too much teaching, and to encourage others to follow in their footsteps, for it is these young men who are the hope of the nation.

Quite recently a tendency has developed to send older men of higher rank abroad, which is a very good thing provided that the younger men are also sent, because they are the ones who will profit most by the experience.

The Japanese have undoubtedly achieved wonders during the last twenty-five years and in order to fully satisfy their national aspirations it is essential that those in authority should give the rising generations the very best opportunities for development. After a few readjustments have been made they may look forward to the future with confidence.

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Resumen por el autor, Edgar Davidson Congdon,
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La distribución y modo de origen de los tabiques y paredes del seno esfenoidal.

En 212 senos esfenoides, diez y siete tabiques y filas de espuelas están situadas total o parcialmente en la zona generalmente ocupada en un periodo anterior por la sincondrosis conoesfenoidal. Cuarenta y tres estaban situadas en la zona prebasiesfenoidea, treinta en la alarbasiesfenoidea, nueve en la alaralisfenoidea y sesenta y nueve en la alispresfenoidea o concoalisfenoidea. La anchura de estas zonas fué tomada de tal modo que se incluyó el territorio ocupado por todas las sincondrosis, menos las mas aberrantes. Solamente se encontraron algunos tabiques que no correspondían a ninguna de las zonas. Los tabiques situados entre los senos tienden a colocarse en los planos de las sincondrosis mencionadas, asi como las paredes lateral y posterior de los senos. Por la relación entre el tiempo transcurrido entre el desarrollo del seno y la osificación de las sincondrosis esfenoides es probable que la mayor parte de los tabiques resulten del encuentro del seno en vías de crecimiento con partes de las sincondrosis que no se han osificado todavía. No se sabe si persiste una condensación del hueso esponjoso después de las sinostosis de las sincondrosis intraesfenoides ayudando de este modo en la formación de los tabiques. Cortes transversos de sus planos de fusion en treinta y un casos de esfenoides fetales no demostraron la presencia de tal condensación. El autor no pudo examinar secciones de cráneos de niños. La posición primitiva de la sincondrosis esfenoccipital puede marcarse por una condensación en el cráneo adulto. El carácter de los tabiques esfenoides no favorece el supuesto de que estas estructuras se retienen después del periodo de crecimiento como soportes de las paredes del seno. Parecen ser productos del desarrollo imperfecto del seno los cuales no conservan función alguna importante, bien sea mecánica o de otra clase.

Translation by José F. Nonidez
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THE DISTRIBUTION AND MODE OF ORIGIN OF SEPTA AND WALLS OF THE SPHENOID SINUS

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THREE PLATES (ELEVEN FIGURES)

The sphenoid sinus has been described as the most variable in form of any bilateral cavity or organ of the human body. Its proportions have taken on a practical interest since its drainage has become a practice of surgery. The bony plates and rows of spurs which project from its walls also affect drainage by increasing the variety of its relief. In 212 sinuses, 122 septa and rows of spurs were found. In spite of the variety in form and position of these projections, their description and explanation have received scant attention. Doubtless if they had been visible in skulls uncut or with cranial cavity exposed, such as make up a large part of most collections, they would have long ago been given the same careful scrutiny which nearly every detail of the skull has received.

Two writers have given attention to the septa. Toldt in 1883 discussed the sagittal plates which project from the lateral or posterior sinus wall in connection with his description of the development of the sphenoid. He believes that they coincide with the plane at which the alisphenoid ossification centers unite with the body of the bone and that they have arisen because for some reason the tissue here was able to resist absorption during the growth of the sinus.

Cope has recently ('17) applied the same principle to the explanation of the partial septa in general making use of a number of the numerous fusion planes which occur in the sphenoid. He also believes that the various forms assumed by the sinus are to be explained by the halting of its walls during development at

various of the fusion planes. His interesting effort to find a common explanation for the amazing variety of sinus forms is based upon the examination of nearly three hundred sinuses. Because of the largely descriptive character of the paper, it suggests the need of testing the frequency of the coincidence of the septa and walls with the synchondrous planes statistically.

The present study is devoted in large part to a statistical examination of this kind. Attention is also given to the nature of the resistance which may have been offered to the growing sinus at the synchondrosis planes. In conclusion, another explanation of the presence of the septa is considered, based upon their possible function as a support to the walls of the sphenoid.

Complete sinuses were studied with the aid of large windows cut in their superior walls or in the intersinus septum.¹

Pantagraph drawings were made of the superior surface of forty-eight sphenoids and the septa plotted upon them. These were later discarded for written descriptions of the septa in order to better indicate their position in three dimensions and their relation to the markings of the early fusion planes. A graphic method was retained for the records of the intersinus septum. Its course midway of floor and roof was marked on a stenciled outline of the superior surface of the sphenoid.

All markings which could be found in the adult bone for recognizing the former position of the synchondroses were made use of in deciding whether the septa coincided with them. It is possible to find the position of some synchondroses very exactly, while others vary in position rather widely with reference to the adult landmarks of the sphenoid. The writings of Toldt ('83), Sappey ('67), Cleland ('62), Sternberg ('90), and von Spee ('76) were directly consulted in determining the position and time of fusion of synchondroses. References were obtained from the studies of Rambaud and Renault ('64), Hannover ('81), and Virchow ('59). Sections of thirteen late foetal and early infantile heads were utilized, as well as four somewhat older skulls.

¹ This term has been adopted in the absence of any satisfactory name for the partition between the two sinuses. The commonly used expression, 'median septum,' is not correct, because it is more frequently lateral than median.

The numerical expressions obtained from the tabulation of the septa are ratios expressing the frequency of occurrence of septa in the regions of the synchondroses planes. Because synchondroses would have an opportunity to form septa only if a sinus extended into their territory, a condition by no means always fulfilled, the frequency of septa at each synchondrosis plane was expressed in relation to the number of sinuses that included a third or more of their plane, and not with reference to the total number of sinuses examined.

SEPTA IN THE REGION OF THE LATERAL FUSION PLANES

Three synchondroses meet below the posterior root of the lesser sphenoid wing at about the time of birth. One of these extending anteriorly from their line of union is between the alisphenoid and the presphenoid centers. The presphenoid may give way anteriorly to the concha to form an alisphenoid-conchal synchondrosis. The two posterior synchondroses lie on either side of the wedge-shaped center of the alar process, and may be termed the alar-alisphenoid and alar-basisphenoid, respectively. In the region at or near these plane approximately three-fifths of all the septa of the sinuses were found.

Near the posterior root of the lesser wing is situated the passageway extending from the upper to the lower surface of the bone, which Sternberg has termed the lateral craniopharyngeal canal. It either disappears or is reduced to a very small caliber in the adult. As Sternberg pointed out, part or all of it may be retained in the free edges of anteriorly facing septa. Since the canal is the remnant of the gap between the ossification centers at the confluence of the three synchondroses, it was found helpful in determining their previous position in the adult bone.

The canal marks the center of an accumulation of compact bone as long as the synchondroses remain, because their cartilages are each covered on both surfaces by a thin layer of compact bone (fig. 8). This may be likened for a portion of the developmental period to a hollow column with flutings corresponding to the compact layers.

The remnants of the lateral craniopharyngeal canal lying in the free edges of the anteriorly facing septa have a very characteristic course, which is often traced by the margin of the septum even where no vestige of the canal is present. It is convex forward with the upper end terminating near the posterior root of the lesser wing. It is inclined laterally in its lower part and bends more markedly in this direction as it nears the roof. The posteriorly facing septa forming the anterior group also may show canal remnants, but not so frequently.

One hundred and twenty-eight laterally placed septa were found to converge toward the region of the canal and lateral column. Some came from the anterior and anterolateral and others from the posterior and posterolateral walls. Between the two groups there is a lateral region with but few septa. A not inconsiderable number of the septa are mere ridges or rows of spurs, but the majority are plates of considerable width.

Among 162 sinuses containing a third or more of the fusion planes of the two posterior synchondroses, fifty-two anteriorly facing septa were found. This gives a frequency of thirty-two and a fraction per cent. Because these septa lie in the region not only of the lateral column, but of the alar-alisphenoid and alar-basisphenoid synchondroses, the question is raised of the relative importance of the column and of the planes as possible factors in producing the septa. Cope ascribed the septa to the alar-basisphenoid synchondrosis. Toldt expressed the belief that they arose at the alar-alisphenoid plane. Another possibility is that the lateral column may have given rise to them after the smaller accumulations of compact bone of the synchondroses has disappeared. In that case we must suppose that the two recesses formed as the sinus advanced on either side of it did not fuse after having extended past it, but still remained separated by a thin partition. This reaction of the osteogenic layer of one sinus wall toward the periosteum of an adjacent sinus wall is the rule in development, as is shown by the numerous thin partitions separating various sinuses of the skull.

The position of the anteriorly facing septa relative to the planes of the two synchondroses was tabulated to find whether they

fell in the zones usually occupied by these planes or whether they indicated by extending out from the lateral column in some other direction that it alone could be responsible for their formation. In the adult the alar-basisphenoid plane is marked on the lower surface of the bone by a shallow, often poorly defined groove which is the remnant of a deep cleft in the new-born sphenoid. The position of the anterior end of the plane is indicated by the lateral column. A zone about 6 mm. wide lying partly under the carotid groove and partly internal to it was taken as the territory of the synchondroses in the moist preparations. The markings of the cleaned bones often allowed a closer delimitation. Thirty of the fifty-two septa and rows of spurs pointing anteriorly toward the canal were classified in this plane (fig. 10, b). In many cleaned sphenoids it could be shown that the groove on the under surface of the bone extended up for a few millimeters into the septa and spurs. Frequently the septa, while keeping to the plane antero-inferiorly, were deflected from it posteriorly and above. This is to be expected, because the posterosuperior portion of the synchondrosis disappears long before it could exercise any influence upon septum formation.

The former position of the posterior end of the alar-alisphenoid synchondrosis is defined in the adult by the opening of the canal of the pterygoid nerve below and the lateral border of the lingula above (fig. 3, a). Anteriorly it is marked by the lateral column. Nine of the fifty-two anteriorly facing septa lay in its plane (fig. 3, b). In one sinus there were septa in both the alar-alisphenoid and the alar-basisphenoid planes.

Thirteen of the posterior group of lateral septa which do not fall within either of the synchondrosis planes can be better interpreted after the distribution of the second group of lateral septa is considered.

The anterior group occurred with the surprising frequency of forty and a fraction per cent in 171 sinuses. The ali-presphenoid synchondrosis extends through this region, except where it is occasionally replaced anteriorly by the concha-alisphenoid union. It extends from the lateral craniopharyngeal canal and its lateral column anteriorly and laterally to reach the inferior

orbital fissure on its anterior border and close to its medial end. All of the septa of this group fall within the region of the synchondrosis if we make the reasonable assumption that its zone of distribution varies from the anterior border of the fissure through a band about 8 mm. wide (figs. 2, c, and 11, a).

All but twenty-two of the 130 lateral septa are situated in synchondrosis zones, and were very probably derived from these structures. Nine septa of the twenty-two point toward the lateral column from the sinus wall a little posterior to the inferior orbital fissure. While they lie behind the zone marked out for the ali-presphenoid, it may be that especially aberrant synchondroses gave rise to them because they are in an adjacent region and few in number. The explanation seems improbable for those farthest behind the fissure. In two instances they could not possibly have arisen in this way, because ali-presphenoid septa were also present (figs. 1 and 6). It is probable since the nine septa faced the canal region that some of them were formed from the lateral column without aid of other portions of the synchondroses in the manner already described. The thirteen posterior septa of the lateral group which did not lie in either synchondrosis zone were situated near to one of them. It is probable that they also arose either from aberrant synchondroses or from the lateral column alone.

Not all septa in the lateral zones can have begun their development at the lateral columns. Sometimes an ali-presphenoid and an anteriorly facing septum occur in the same sinus. Then the sinus must have extended laterally past the column either in front or behind it. Most commonly it passed anteriorly to it. It is also not rare to find a single septum traversing the alar-basisphenoid and the posterior part of the ali-presphenoid zones. The sinus in these instances evidently broke through the anterior synchondrosis plain far forward.

Not only are there septa occupying territory in two zones, but several were found with a triradiate arrangement (figs. 2, 8 and 1). Those of this type in which the bone had been denuded of mucoperiosteum showed the remnant of a lateral craniopharyngeal canal at the line of confluence of the three plates. In all

of the triradiate septa two and usually three of the plates lay in different zones. These structures are the most striking illustrations of the apparent coincidence of the septa and zones.

The septa vary from broad plates to mere ridges or rows of spurs. The ridges frequently are found in small sinuses which had passed but a little way beyond the region of the lateral column. These are usually thick and rounded at the edge. Toldt believes that the broad lateral septa first appear as ridges and that when the posterior wall of the sinus retreats they elongate backward correspondingly. He points out that all stages in this process are to be found in adult sphenoids. Toldt's observations can be easily confirmed. The same series can be found for the posteriorly facing septa also. It has been seen, however, that not all of the lateral septa begin at the region of the lateral craniopharyngeal canal. The process of septum growth is apparently the same, no matter where in a synchondrosis plane the ridge first projects into the sinus.

Another type of ridge is found which probably represents the last remnant of a septum, the rest of which has been resorbed. It has a thin edge and may lie on a wall or floor far removed from the region of the canal. The intermediate stages between these and the original complete septa are present.

During childhood and youth the sinuses are enlarging while the synchondroses are disappearing. It is necessary to know the relative time of the two processes to find how the synchondroses could affect septum formation. The cleft in the alar-basisphenoid was found to have become shallow in the skull of the adolescent period, but to still project far up into the bone in a sphenoid of about the seventh year. From Sternberg's observations, based upon twenty skulls of ages from six to eight years and from a small amount of other data, the sinus is probably usually in contact with the canal before the tenth year and has progressed far enough to expose part of the cleft marking the alar-basisphenoid union by the twelfth year. The conditions are evidently present for a frequent encounter between the sinus and the upwardly projecting compact bone of the cleft.

The alar-alisphenoid synchondrosis is more remote and would be reached later by a growing sinus. It is already obliterated, according to Toldt, by the sixth year. In agreement with the supposition that synchondroses give rise to septa, few projections were found in this zone. The ali-presphenoid synchondrosis is also closed by six, though many septa mark its position. The great frequency of septa at this plane is a cause for surprise, because the sinus is not supposed ordinarily to reach the region till several years later.

SEPTA OF THE CONCHA-PRESPHENOID PLANE

The most anterior of three more or less frontally placed planes of fusion encountered by the expanding sinus lies at the junction of the concha and the presphenoid ossification centers. It can usually be distinguished on the inferior surface of the body of the adult sphenoid if the alae of the vomer be removed, though it is not always to be seen even then. The conchae appear as two triangular plates applied to either side of the sphenoidal crest and rostrum with apices lying well posteriorly on the lower surface of the bone. Anteriorly the fusion line is not usually visible on the adult bone, but it is said by Toldt ('83), Sappey ('69), and Cleland ('62) to come out at the level of the sinus aperture. The concha shows a wide range of variation which affects the position of the plane of fusion with the presphenoid. The most useful feature of the plane for determining its former situation in the adult bone aside from its location is that it faces anteriorly laterally, and inferiorly unlike the pre-basisphenoid plane behind it.

In seventeen sinuses septa and spurs were found in its territory (fig. 8). They arose from lateral wall, floor, or intersinus septum and extend in the direction characteristic of this plane. Toldt describes in detail the gradual absorption by the growing sinus of the posterior compact wall of the concha and its entrance into the presphenoid. In examining the position of the intersinus septum, it will be later seen that there is reason for believing that it sometimes follows this plane for a greater or lesser distance. Occurrences of this kind here are as infrequent as is the forma-

tion of partial septa. It would be interesting to know why septa are so rare here when they are so very frequent at the ali-presphenoid plane, though it comes in contact with the sinus at a later period.

SEPTA OF THE PRE-BASISPHENOID PLANE

The plane of contact between the presphenoid and basisphenoid usually faces frontally, but its situation in nine late foetal and early infantile sphenoids was found to vary through a rather wide range in an anteroposterior direction. A zone was accordingly marked off as its territory which included the region under the tuberculum sellae and below the anterior third of the hypophyseal fossa.

Forty-three septa and rows of spurs were found in 143 sinuses, giving a frequency of thirty and a fraction per cent. They were found most commonly on the roof near the midline and on the medial septum. Their grouping in the medial part of the plane is probably explained by the well-known fact that there is a much later retention of the synchondrosis here than in its lateral part. Cope finds the septa to be present in 20 per cent. The agreement is as close as is to be expected, in consideration of the probable differences in the methods of delimiting the zone of the synchondrosis used in connection with the two computations.

The disappearance of the synchondrosis may not be complete till the thirteenth year, according to Kölliker ('79) and from Toldt's observations ('83) not until the end of the growing period. From the evidence already given upon the rate of growth of the sinus in childhood, it is probable that it would frequently reach the basisphenoid in time to come into contact with remnants of the synchondrosis.

A GROUP OF SEPTA APPARENTLY NOT ORIGINATING FROM A SYNCHONDROSIS

Eleven septa were found among those not lying in any synchondrosis plane which were of a common type (fig. 7). They extended anteriorly from the posterior wall of basisphenoid sinuses parallel to the plane of the hypophyseal fossa. Sometimes the wall had receded farther above than below them during

the backward extension of the sinus so that they came off from the edge of a step. An explanation for their appearance is suggested in several late foetal and early infantile sphenoids by a bony plate lying in the plane of the septa at the center of the basisphenoid. It is connected with the fact that osseous tubes occur which carry blood-vessels into the bone and serve as the support for a vascular plexus at the center of the sphenoid not unlike that which is associated with the basivertebral veins in the centers of the vertebrae. It is probable that a sufficient portion of the layer occasionally remains in youth to give rise to the septa. In two foetal sphenoids the spongy bone was much more compact below the plate than above it. It may be that a condition of this kind retards the progress of the posterior wall below the plate relative to the part above it, thus producing the step.

DISTRIBUTION OF THE INTERSINUS SEPTA

The septum intervening between the pair of sphenoid sinuses is frequently described as median, but it was found to keep to a median zone approximately 6 mm. broad in only twenty-five septa out of eighty-six. Sixty-nine per cent extended outside its boundaries and, as will be seen, a larger number than kept to the median line showed a deflection far to the side.

The statement is occasionally found that deflection of a septum is more frequent toward one side than the other. Of 102 septa, some of which were slightly defective, no justification for this claim was found. Thirty-eight were turned to the right and forty-one to the left. Twenty were in an intermediate position.

There is a noticeable tendency for intersinus septa to take the course of certain fusion planes. Seven septa showed the characteristics of the concha-presphenoid plain not only in being deflected to the lateral side of the sphenoid body anterior to the basisphenoid, but also by facing laterally and inferiorly (fig. 5). Eight other septa placed somewhat further back probably in some instances also were coincident with this plane.

A large number of the septa, twenty-seven in all, ended in the region of the lateral column. Sixteen ended farther back on the wall in the vicinity of the lateral synchondroses.

Cope believes that many deflected intersinus septa result from the fact that one sinus is able to expand into the opposite side of the sphenoid because its companion sinus, which would usually have preempted the space, has been retarded by the pre-basisphenoid synchondrosis. He describes a septum which kept to the midline in the presphenoid and bent at right angles to pass laterally along a pre-basisphenoid plane. In this instance one sinus was evidently completely blocked at the pre-basisphenoid plane. The failure of a sinus to pass the concha-presphenoid junction explains in a reasonable manner the presence of intersinus septa lying along this plane.

The ending of many oblique intersinus septa in the region of the lateral craniopharyngeal canal is evidence that the synchondroses do, as Cope believes, play a part in the formation of this type also by bringing an advancing sinus to a halt. Local condensations of spongiosa not originating from synchondroses, such as can often be found in the sphenoids of the new-born, probably also retard sinus growth. It may be that they are a cause of the small bulgings of septa which are those entirely unassociated with fusion planes. It is of course very probable that factors affecting the degree of activity of the osteogenic tissue also often help to determine the relative progress of a pair of sphenoid sinuses.

RELATION BETWEEN SINUS WALLS AND TWO SYNCHONDROSIS PLANES

The fusion plane of the occipital and the sphenoid bones is so removed from the region of origin of the sinus that only in a small percentage of cases does the sinus invade the occipital bone. No well-marked projection could be found which could be ascribed to the synchondrosis. Its influence on the position of the posterior sinus wall can be readily examined by means of the frequent sagittal sections which occur among the dry and moist preparations.

In sections of thirteen skulls with the synchondrosis still present it was found to vary from a position a little behind the dorsum sellae to the middle of the clivus. Markings are found in varying combinations in adult skulls which give good evidence

as to its former position (fig. 4). They are: *a*) a line separating a rough anterior part of the clivus from a smooth posterior portion; *b*) one or more small elevations extending across the clivus; *c*) a roughening on the under surface of the bone; *d*) a poorly defined condensation of the spongy bone. The zone of distribution of the synchondrosis was taken as extending from a plane 3 mm. behind the dorsum sellae to a little past the middle of the clivus.

The number of sinuses ending in this zone was compared with the number ending in the region of approximately equal extent intervening between it and the territory of the pre-basisphenoid synchondrosis. Twenty-three sinuses terminated in the anterior division and fifty-one in the posterior division. Eight were on the boundary line. The tendency for a normal sinus to reach the posterior zone is probably greater than the figures indicate, because any abnormal conditions retarding sinus development would tend to throw the sinuses into the anterior group. Upon the other hand the ending of so many sinuses in the posterior zone is not a strong indication that they lie in the synchondrosis plane, because the region is so extensive.

From among the sphenoids with sinuses ending in the posterior zone thirty-six cleaned skull fragments were found which permitted a closer examination of the relationship upon the surfaces exposed by a sagittal cut. In twenty-six of them there was evidence of varying value for the position of the synchondrosis plane. In nineteen the sinus appeared to touch it. In seven there was an interval between. In eight sinuses evidence for the former position of the synchondrosis could not be found. Two had passed what was probably the plane. The posterior walls of sinuses which reached the plane were sometimes in contact over a small area, but frequently they were well flattened out upon it. The inner surface of the wall occasionally had projections and pits which resembled the irregularities frequently found on the posterior surface of the sphenoid before fusion with the occipital bone.

The time of obliteration of the synchondrosis is usually given as somewhere between the thirteenth and the twenty-second year. Data regarding the time at which the sinus reaches its adult pro-

portions seems to be very meager. It is usually stated that this occurs at puberty. Occasionally a slow growth in adult life is said to follow the early period of rapid enlargement. If the sinus reaches the synchondrosis at puberty or even somewhat later, it would probably encounter unabsorbed remnants of the synchondrosis.

Sinuses were grouped to show whether the wall stopped with especial frequency in the alar-basisphenoid or alar-alisphenoid zone. It was found that because the lateral walls are frequently rounded instead of flat like the septa they could be less satisfactorily classified. Twenty-seven out of 114 sinuses had a lateral wall touching the alar-basisphenoid zone. Sixteen were scattered over territory lying a little farther laterally. The wall of the remaining sixty-seven sinuses lay beyond the alar-alisphenoid one. There is a parallelism between the grouping of septa and walls in this region. A considerable number of each are found at the alar-basisphenoid zone, a few at the alar-alisphenoid zone, and there are a few scattered in the vicinity. Reasons for anticipating the much more frequent encounter of the sinus with the alar-basisphenoid than with the alar-alisphenoid synchondrosis were given when discussing the septa.

CLASSIFICATION OF SPHENOID SINUSES

Cope has divided sphenoid sinuses into three groups, according as they are entirely anterior to the plane of fusion of the presphenoid and basi-sphenoid, or extend back of a plane a little anterior to the clivus, or occupy an intermediate position. He found seventy-two ending in front of the basi-sphenoid, 155 of those extending most posteriorly, and sixty-five of the intermediate type.

The arrangement of ossification centers of the sphenoid in an anteroposterior series in either half of the bone furnishes a natural means of sinus classification. Four types can be distinguished from their relation to the centers. They are: 1) those anterior to the concha-presphenoid plane ('conchal' sinuses) (fig. 5); 2) those extending into the presphenoid, but not into the basisphenoid ('presphenoid' sinuses); 3) those reaching into

but not beyond the basisphenoid ('basisphenoid' sinuses) (figs. 4, 5, etc.), and finally, 4) those extending into the basilar part of the occipital bone which may be termed 'occipitosphenoid' sinuses. It has been found that the concha-presphenoid and the sphenoccipital synchondroses probably bring some sinuses to a halt. Because septa are found at the pre-basisphenoid plane and from certain other considerations, it is probable that the posterior wall also frequently comes to a stop at this synchondrosis. The classification evidently corresponds to a natural grouping of the sinuses.

Nine sinuses were classified as conchal and eight were undetermined as between the conchal and presphenoid types. Forty-three are presphenoid. Both basisphenoid and occipitosphenoid are included in the remaining one hundred and twenty-one since it is not possible to distinguish except under especially favorable conditions between the two types. As has been seen, probably only a few fall in the last-named group.

Cope found seventy-two sinuses ending in front of the pre-basisphenoid plane and 220 behind it. The Stanford material gave fifty-two anterior and 121 posterior to the plane. Expressed in percentages, the frequency of the two anterior groups were twenty-four and thirty, respectively. The correspondence between the two ratios is as close as could be expected without identity in the method of dividing the areas and of choosing the material.

The significance of the differing frequency of the four sinus types is dependent upon the manner in which their growth periods are distributed through life and upon the age of the sinuses. If, for example, they enlarge continuously and at a uniform rate throughout life, the probability would suggest itself that the conchal and pre-sphenoid sinuses came from the youngest skulls and the occipitosphenoid from the oldest. It will be possible to learn approximately the influence of these factors upon the ratio which has been given. Seven out of nine of the conchal sinuses, twenty-seven of the presphenoid type as well as eight intermediate between the two had plainly completed their development in a posterior direction because

they were hemmed in behind by their companion sinuses. The two conchal sinuses not hemmed in were from an individual fifty-five years of age. Twenty-seven of the forty-three presphenoid sinuses also were bounded posteriorly by intersinuses septa. Many of the remaining sixteen were from skulls apparently from middle life or beyond. It is clear, then, that the conchal and presphenoid sinuses had most of them nearly if not completely reached their adult volume. The proportion between the basisphenoid and occipitosphenoid groups was probably changed slightly from its true value to the benefit of the larger type by old-age absorption. Taking into account these various considerations, it is clear that the frequencies obtained for the different types may be taken as only an approximation to the correct figures for the adult period. This inference is based on the fact that the dissecting-room material from which most of the bones came contained 50 per cent more bodies of individuals between the ages of sixty and eighty than of those between twenty and forty, also the skulls with the basisphenoid sinuses showed more general absorption than did the other groups.

THE RELATION OF SYNCHONDROSES TO SEPTA AND WALLS

Discussion and conclusions

Much evidence has been given to show that the septa are largely grouped in the zones formerly occupied by seven synchondroses. It is significant that precisely these joints consolidate at a somewhat advanced period in postnatal life, while the position of fusion planes which were obliterated before birth are not marked by septa. The mere occupation by a septum of the general region in which a synchondrosis formerly lay does not of course prove a causal connection between the two structures. The fluctuation in position of some synchondroses was so great that rather broad zones had to be marked out to cover the range of their former positions. Most of the septa, however, not only took the direction of the synchondroses, but over 90 per cent of them lay within their zones, although the total capacity of the zones was but half that of a sinus of average

size. There were also various details of septal structure confirming the relation of septum and synchondroses, such as the presence of lateral craniopharyngeal canals in the septa and the occurrence of triradiate septa whose three bony laminae lay in three confluent synchondrosis planes. While there is not absolute proof of the formation of any single septum from a synchondrosis, the conclusion is scarcely avoidable that a large proportion of them are derived from this source.

A brief examination of a series of maxillary and frontal sinuses is sufficient to convince one that many of their septa could not have come from fusion plains of ossification centers, since they lie at a distance from the position which these formerly occupied. There were a few sphenoid septa also that are entirely independent of synchondroses. They apparently owed their origin to compact bone developed within the basisphenoid center as a support for a vascular plexus. It is of course impossible to say whether the small group of septa which did not fall in any zone were due to synchondroses in unusual positions or to some unknown cause. Some septa also evidently seem to have arisen from the lateral column of compact bone at the line of union of the three lateral synchondroses, but were otherwise independent from them.

Intersinus septa, while usually close to the median line at their anterior end, frequently take an oblique course more posteriorly which will bring them to one of the lateral fusion planes. They may assume a position which is apparently in exact correspondence with a concha-presphenoid plane.

Evidence has been given in confirmation of Cope's view that some deflected intersinus septa are in part due to the enlarging of one sinus across the midline when the other has been retarded by the pre-basisphenoid synchondrosis. It is probable that retardation may also take place at the concha-presphenoid plane, yet not all deflections can be explained in this way. The condensations of spongy bone found in the sphenoids of the new-born may also have retarded sinuses.

It was found that not only septa, but also sinus walls may show a grouping at synchondrosis planes. Observations on the position of the posterior wall of basisphenoid sinuses allow the esti-

mate that in 50 per cent it is situated at the sphenoccipital synchondrosis. Nineteen per cent of the lateral walls of the basisphenoid sinuses probably ended at the alar-basisphenoid plane. It is to be expected that other factors, among them, the density of the spongy bone, would play a part in determining the position of sinus walls.

It was found by a comparison of the time of fusion of ossification centers and of the approach of the growing sinus that remnants of most synchondroses associated with septa would frequently remain long enough to resist the osteogenic layer and so give rise to septa. The ali-presphenoid synchondrosis is apparently an exception, because it is said by Toldt ('83) to be obliterated at six, and according to some writers at a still earlier period, while the sinus is probably usually just entering the presphenoid at this time. A possible explanation is to be found in Cope's claim that especially resistant bone remains after a synchondrosis has disappeared. He says, ". . . there is evidence to show that the bone formed at the line of fusion of bony centers may be and often is of a denser and more resistant material than the tissue on either side of the line." He does not discuss the nature of this evidence.

Just after the fusion of a synchondrosis it is to be expected that an accumulation of compact bone would be present, since a thin layer was previously in contact with either surface of the cartilage, but its persistence through any considerable subsequent period cannot of course be taken for granted. A number of regions were examined in the sphenoids of late foetal and early infantile skulls where synchondroses had disappeared not very long before in search for material more dense than the usual spongy bone. The joints in question are the lateral part of the pre-basisphenoid and the posterior part of the alar-basisphenoid and the median presphenoid and basisphenoid. The latest of these to fuse was at the plane of union of presphenoid and basisphenoid. It disappears two or three months before birth. In the thirty-one individual regions of fusion which were examined none showed any condensation. It is to be anticipated, however, that the compact bone would be absorbed less rapidly

after birth because of the general slowing up of growth as development proceeds.

Occasionally an ill-defined condensation of spongy bone was found at the plane of the sphenoccipital synchondrosis in the adult sphenoid. It is probable that its disappearance would proceed at a much slower rate than in the other synchondroses whose fusion occurred before birth. It may be that the alipresphenoid synchondrosis, since it fuses after birth, though at a much earlier period than the sphenoccipital joint, may leave not only traces of dense bone, but also cartilage or fibrous remnants long after its complete obliteration on the surface of the sphenoid has occurred. Certainly, as has been seen, portions of the wall of the craniopharyngeal canal which constitutes its posterior end are to be found occasionally even in the adult.

THE RELATION OF SEPTA TO THE SUPPORTING FUNCTION OF THE SPHENOID

Many septa give the impression after a cursory examination that they may be of importance in strengthening the walls of the sphenoid sinus, although their relationship to the synchondroses has led on the preceding pages to an entirely different explanation of their presence. Cope ('17), while also occupied in tracing their origin to the synchondroses, termed those which lay under the carotid group, carotid buttresses. Gibson ('08) is another writer who has stated that the septa serve as supports.

Many individual septa seem well adapted to a support of the sinus wall, but the location and form of others are incompatible with such a function. It is also to be remembered that the occurrence of septa is only occasional in any one locality, and it does not seem correlated with conditions especially requiring a support. They are abundant in thick-walled sinuses and young sphenoids with but small cavities may have thick ridges. On the other hand, large thin-walled sinuses usually have thin septa. Occasionally sinuses are crowded with septa though showing no especial need of wall supports, and again a very roomy and thin-walled cavity will have none. Of two companion sinuses

very similar in form and thickness of wall, one may have a septum and the other not. Many septa take the form of ridges at the junction of intersinus septa and roof or upon the floor and in other positions where there is no likelihood of an especial need for support (fig. 2). The intersinus septum may cut across one corner of the body of the sphenoid, leaving a thin plate of bone under the greater part of the sella turcica entirely unsupported. Many septa have jagged or variously roughened free edges that could have no significance (fig. 11) in strengthening the walls.

Wolff ('92), Triepel ('08), and others have made familiar many details of bony architecture which seem almost perfectly adapted to resist stresses and strains. Wolff also has brought forward evidence that the osseous structure may take on a new form in adult life in response to changing mechanical demands. It may be asked whether the septa which do not conspicuously lack adaptation to such demands may not either have arisen or have been remolded in response to them, or at least have been retained after the growing period because of their utility as supports. The form and position of the septa furnish no convincing evidence for any of these assumptions. On the contrary, both the form and position of many septa indicate in a striking manner origin from synchondroses, while in these features most of the others lend themselves very readily to the same interpretation. The septa do, of course, strengthen the walls, but the view that this is other than accidental is not only unproven, but improbable.

I wish to express my appreciation to Prof. A. W. Meyer for helpful suggestions and criticisms and to Prof. F. C. Blaisdell, of the Department of Surgery, for the use of anatomical preparations.

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PLATES

PLATE 1

EXPLANATION OF FIGURES

1 Sagittal section. $\times 1$. *a*. Septum in ali-presphenoid zone. *b*. Edge of septum extending laterally and not lying in plane of any synchondrosis. *c*. Septum in pre-basisphenoid zone.

2 Floor of sinus exposed. Septa on floor converging to remnant of lateral craniopharyngeal canal (*a*). $\times 1$. *b*. Septum in alar-basisphenoid zone. *c*. Septum in ali-presphenoid zone. *d*. Septum in pre-basisphenoid zone.

3 Floor of sinus exposed. $\times 1$. Lateral border of lingula (*a*) marking former position of alar-alisphenoid plane in line with septum (*b*).

4 Sagittal section. $\times 1$. Markings giving former position of sphenoccipital synchondrosis at (*a*).

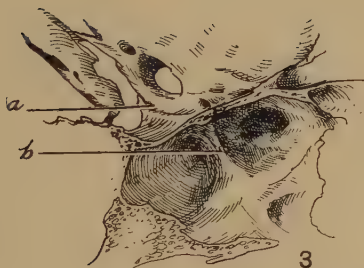
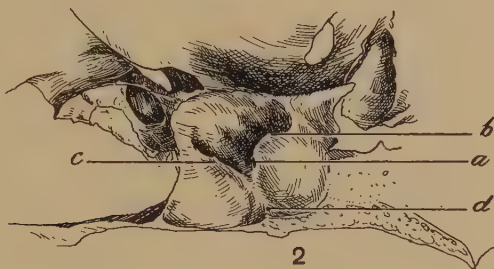
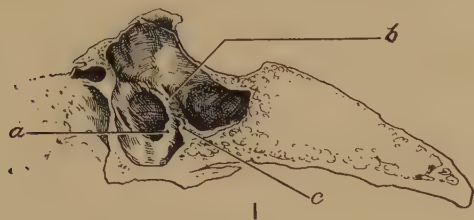


PLATE 2

EXPLANATION OF FIGURES

5 Sagittal section. $\times 1$. Opening in intersinus septum to show a conchal sinus.

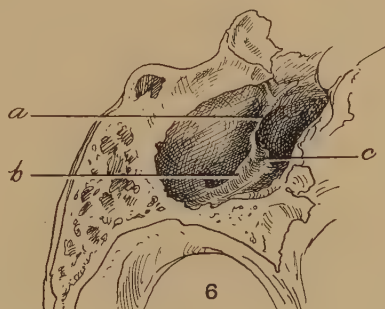
6 Sagittal section. $\times 1$. *a*. Free edge of septum not in zone of synchondrosis. *b*. Septum in alar-alisphenoid zone. *c*. Septum in ali-presphenoid zone.

7 Sagittal section. $\times 1$. Septum (*a*) transverse to long axis of body probably arising from plate in sphenoid of new-born which serves as support of a vascular plexus.

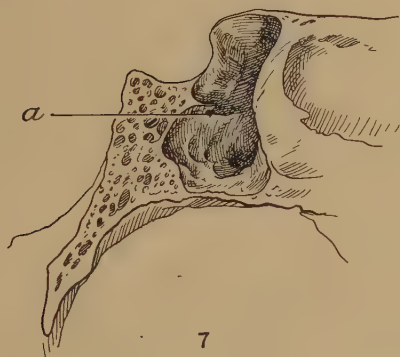
8 Ali-presphenoid septum with portion of lateral column remaining at (*a*). $\times 1$.



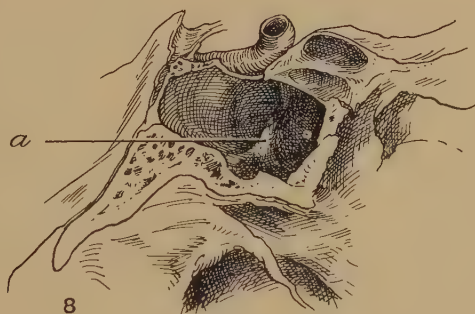
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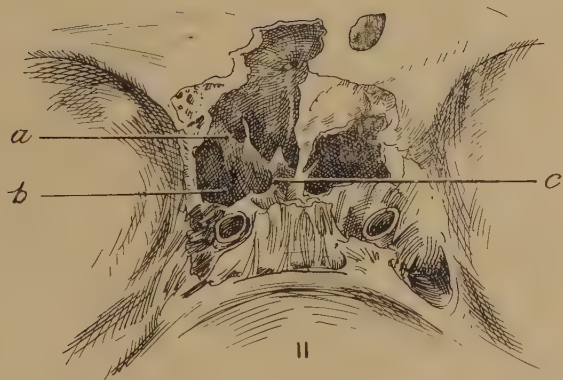
PLATE 3

EXPLANATION OF FIGURES

9 Sagittal section. $\times 1$. *a*. Septum of concha-presphenoid zone. *b*. Aperture of sinus.

10 Frontal section. $\times 1$. *a*. Septum in region of posterolateral group which lies too far forward to be identified. *b*. Septum in alar-basisphenoid zone.

11 Sinus opened from above. $\times 1$. *a*. Septum in ali-presphenoid zone. *b*. Ridge made by canal of pterygoid nerve. *c*. Septum in alar-basisphenoid zone.



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El empleo de roentgenogramas estereoscópicos en el estudio del
sistema circulatorio de los vertebrados.

El sistema circulatorio de formas tales como *Necturus*, la rana común, la tortuga o el gato puede estudiarse ventajosamente por medio de roentgenogramas estereoscópicos. Los vasos sanguíneos del ejemplar que se desea estudiar se inyectan con una mezcla con sulfato bárico en suspensión y después se aplican los rayos X. Se pueden inyectar varios ejemplares, demostrando en cada uno de ellos una parte diferente del sistema circulatorio. Pueden inyectarse las arterias de un ejemplar, la vena portahepática de otro y las restantes venas en un tercer ejemplar. Las exposiciones a la acción de los rayos X se efectuaron utilizando un tubo auto-rectificador de Coolidge capaz de admitir corrientes hasta de 10 ma. Para un animal como *Necturus* se empleó el siguiente dispositivo: La corriente de 8 miliamperios, longitud de chispa de 5 pulgadas, distancia focal de 20 pulgadas; exposición, 6 segundos. Para animales mas grandes es necesario emplear una exposición mas larga. Para obtener roentgenogramas estereoscópicos es necesario hacer dos exposiciones del mismo ejemplar. Se hace una exposición, se mueve el tubo $2\frac{1}{2}$ pulgadas hacia la derecha o izquierda y se repite la misma operación. Cuando se reducen las placas a un tamaño apropiado, se obtienen las positivas y se montan estas últimas dejando entre ellas una distancia de $2\frac{1}{2}$ pulgadas, los vasos sanguíneos y otras partes aparecen en su posición relativa característica cuando se examinan con un esterióscopto ordinario. Las diapositivas son mas satisfactorias que las obtenidas sobre papel. Las primeras se obtienen utilizando placas Seed, las cuales se montan entre placas de vidrio, manteniéndolas en posición por medio de cinta de encuadernar, empleándolas del mismo modo que las positivas hechas sobre papel. Los roentgenogramas preparados de este modo no solo dan excelentes datos para los estudiantes que disecan el sistema circulatorio, sino que suministran un medio para el exámen rápido y exacto de un gran número de especies sin necesidad de disección.

THE USE OF STEREOSCOPIC ROENTGENOGRAMS IN STUDYING THE CIRCULATORY SYSTEM OF VERTEBRATES¹

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TWO TEXT FIGURES AND TWO PLATES

The use of the Roentgen-ray in studying blood-vessels injected with some opaque material was first described by H. Brause ('96). He used metallic mercury in filling the blood-vessels and gives a Roentgenogram of a human hand prepared in this way.

G. H. Parker ('13) described a method of preparing small animals for studying variations in the blood system. The vessels were filled with an injection mass so compounded as to be opaque to the Roentgen-rays and yet firm enough to make subsequent dissection possible.

The purpose of the present paper is to outline the method of procedure in preparing specimens for the study of the circulatory system by means of the Roentgen-ray and in obtaining stereoscopic Roentgenograms. Stereoscopic exposures enable one to study the relations of blood-vessels without subsequent dissection, thus saving a great deal of time. An added advantage is that they afford excellent references for students in comparative anatomy while dissecting in the laboratory.

¹ The writers wish to express their indebtedness to Dr. H. D. Reed for his suggestions and cooperation throughout the progress of this work, and to Mr. L. P. Larkin, of the Department of Physics, for his invaluable help in the work of x-raying specimens. Thanks are also due Mr. R. E. Gove for his enthusiastic assistance.

We are especially indebted to the Department of Physics for the use of their excellent laboratory facilities and x-ray apparatus.

INJECTION MASS

There is need of accurate knowledge of the origin and distribution of blood-vessels, and to make the best of such studies toward true morphology the method employed must be one that will take into account all vessels, both large and small.

It is obvious, therefore, that the material used in filling the blood-vessels must possess the following characteristics: first, it must be opaque to the Roentgen-ray; second, it must be composed of particles fine enough to pass through the smallest vessels without clogging, and, third, it must be easy of manipulation. A suspension mixture of barium sulphate meets all these requirements.

There is one objection to barium sulphate. When it is thin enough to fill the smallest arterioles or venules, it will not give a clear Roentgenogram of the large vessels. This difficulty, however, is easily overcome by injecting first a small amount of thin barium sulphate and following this by as thick a mixture as can be forced into the blood-vessels. If this is done, every vessel will cast a clear shadow.

By using BaSO_4 as an injection mass, satisfactory Roentgenograms have been obtained of the blood systems of *Necturus*, frog, spotted salamander, turtle, and cat. This method will probably prove equally serviceable in studying and demonstrating the circulatory system of the sharks and bony fishes.

METHODS OF INJECTION

As the blood system of *Necturus* was the first one to be studied by us in this way, the method of procedure in making Roentgenograms of this animal will be outlined. The same procedure, with few exceptions, may be used in working with any other form. The specimens chosen for this work should be those which have not been kept in captivity long enough to admit of injury to the external gills. Animals which have been killed twenty-four hours before they are to be used give much more satisfactory results. This allows time for the relaxation of the small arteries connecting the afferent and efferent branchial vessels, thus facilitating the passage of the injection mass into the dorsal aorta.

If all the arteries and veins of a single specimen are injected, confusion of detail will result and the plates will be very difficult to interpret. To obviate this difficulty, several specimens are used, each one injected to show a certain portion of the circulatory system. For example, one specimen might be used to show arteries only; another to show the veins making up the hepatic portal system, and still another to show the branches of the postcava.

For forcing the barium-sulphate injection mass into the blood-vessels, an all-metal veterinarian's hypodermic syringe of 30-cc. capacity and a metal cannula were found to be more satisfactory than either gravity or air pressure.

The following is the method of procedure to be used in preparing *Necturus* for the making of a Roentgenogram. A midventral incision is made through the body wall just anterior to the coracoid portion of the pectoral girdle. This opens the pericardial cavity and exposes the heart. With fine forceps pass a thread around the truncus arteriosus as far cephalad as possible and tie it loosely. With fine scissors make an oblique cut in the truncus at the point where it leaves the ventricle, insert a steel cannula of suitable size and draw the knot down tightly so that the cannula is held firmly in the vessel. The syringe should now be filled with the injection mass and attached to the cannula. By applying a light, steady pressure to the plunger of the syringe, the barium sulphate will be forced through the afferent branchial arteries, fill the capillaries of the external gills, then pass through the communicating branches into the efferent branchial vessels filling both the carotids, the pulmonary arteries, the dorsal aorta and its branches. Pressure should be applied until all vessels are completely filled.

To inject the hepatic portal system, a second animal should be used. A ventral incision in the abdominal wall about 1 cm. to the right of the midventral line is made. Pull out a coil of the small intestine and locate the mesenteric vein, and into it inject the barium sulphate both cephalad and caudad.

A third specimen may be used to show the remaining veins. The truncus arteriosus is ligatured so that no injection material

will pass through the heart into the arteries. An oblique cut should then be made in the postcava just cephalad of the point where it leaves the middorsal line to extend to the liver. The barium sulphate is then injected into the postcava in both directions from the incision.

X-RAY APPARATUS

The x-ray photographs were taken with the usual apparatus. A detailed description is unnecessary, since any machine which is in working order would answer the purpose. The choice of a tube, however, is a matter of some consequence. As much detail as possible is the aim in making x-ray pictures, and it is, therefore, desirable to employ a fine-focus tube. X-ray negatives are shadow pictures. Just as when dealing with the shadows cast by ordinary light, the smaller the source of illumination the sharper the shadow so in x-ray work the smaller the area on the target of the tube from which the x-rays emanate the sharper the shadow cast on the photographic plate. X-rays are set up by the sudden stopping of the rapidly moving electrons by the target. If these electrons are focused by a concave mirror so that they all strike the target at the same spot, the x-rays would emanate from this place as a point source. This is an ideal focus for a tube and cannot be attained in practice because of the great amount of heat generated when the electrons are stopped. A fine-focus tube, however, approaches this ideal focus and gives good detailed shadows.

In making these experiments a self-rectifying Coolidge tube capable of taking currents up to 10 MA. was found very satisfactory. The advantage of using a Coolidge tube lies in the fact that it is easier to control than the gas tube. The Coolidge tube differs from the old gas tube in that the source of electrons is different. An x-ray tube will not take any current if there are no electrons present, since these are the 'carriers.' In the gas tube, the high electric stress applied to the tube breaks up the gas into electrons and a positive residue. On the other hand, a Coolidge tube is as near a perfect vacuum as is now possible. At

the cathode there is a small filament (similar to that used in an ordinary flash-light) which is heated by an auxiliary circuit supplied by a small step-down transformer. In this tube there is no source of electrons except the heated filament. The hotter this filament becomes the more numerous are the electrons given off and consequently the greater the amount of current taken by the tube. By installing a rheostat in the auxiliary filament circuit it is very easy to regulate the temperature of the filament and in this way control the amount of current that the tube will take. In the gas tube it is very difficult to control the electron supply, since the amount of gas in the tube (the source of electrons) must be increased or decreased. This is accomplished by a device called a 'softener,' which only the experienced operator can employ with good results.

PROCEDURE IN MAKING EXPOSURES

For *Necturus* it was found by trial that the following setting, using a self-rectifying Coolidge tube, gave the proper exposure—current of a 8 MA., 5-inch spark gap, 20-inch target-plate distance, and 6 seconds' exposure. The choice of a proper target-plate distance (distance of target in tube from the photographic plate) (fig. 1) is of considerable importance in this work, as this factor in the setting has a direct bearing on the detail obtained on the plate. If the plate is too near the tube, the shadow will be greater in size than the object and will lack detail. If the plate is at the proper distance, the shadow will be nearly the same size as the object and will be sharp.

The preceding paragraph gives only the approximate setting, as it was found necessary to make slight changes constantly in order to obtain the proper exposure for the varying density and thickness of the specimens. Only the rays which penetrate the specimen and strike the plate have any effect on the emulsion. All those that are absorbed in the tissue are lost. Absorption of x-ray radiation depends on, first, the density of the absorbing material (the specimen being photographed); second, the thickness of the absorbing material, and, third, the quality of the radiation, i.e., the degree of penetration possessed by the x-rays.

All materials do not have the same density or, in other words, they do not absorb the radiation equally. That is, each particular kind of material has its own absorption factor which depends

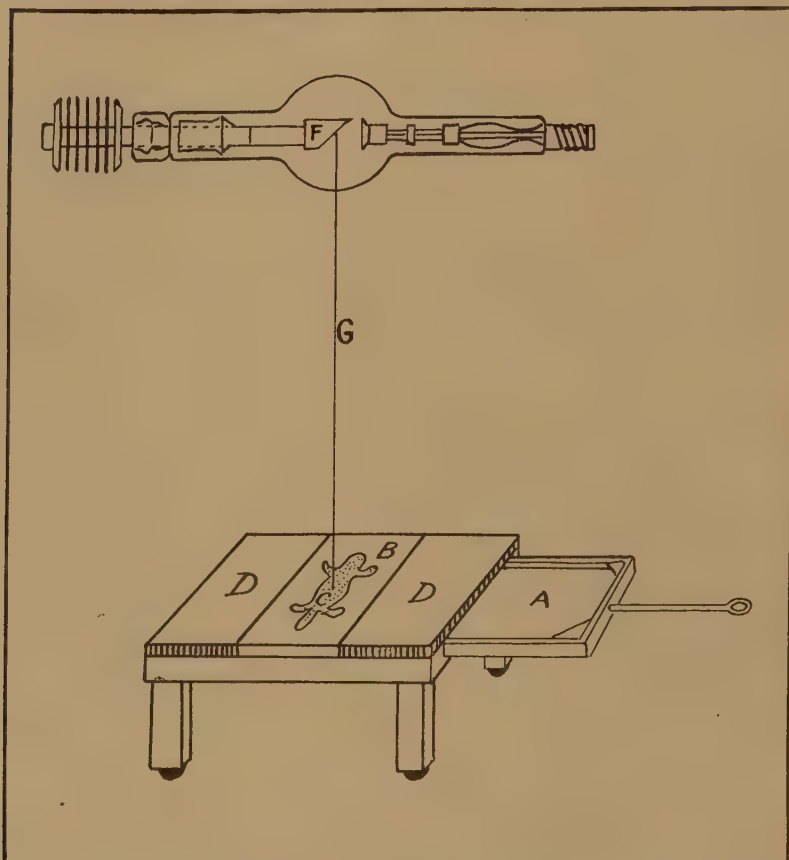


Fig. 1 Diagram of x-ray tube and plate-slide tunnel. A. Plate holders taking $8 \times 10\frac{1}{2}$ inch plate. B. Glass or celluloid plate. C. Specimen. D. Lead plates. F. Target. G. Target-plate distance 20 in.

on the nature of the substance itself. This absorption factor holds only for a given quality of radiation. Each tissue has its own absorption factor or density. Bone absorbs more radiation than muscle under similar conditions. Two different masses of

muscle may have different absorption factors. Thus it was found that of two *Necturi*, equal in size, one would absorb more of the incident rays than the other, with the result that one plate would be properly exposed and the other would not. To obviate this variation in the density of the specimens, the time of exposure must be increased or decreased by an amount which must be determined by trial.

Of two specimens one thicker than the other, the thicker specimen will obviously possess a higher absorption factor. Thus a cat will absorb more radiation than a *Necturus* not so much because the tissue of a cat has a greater density, but because the cat is a larger animal than a *Necturus* and the rays must pass through more tissue before reaching the plate. An increase in the time of exposure will also obviate this increase in thickness, unless the part is very thick and dense when an increase in the applied voltage is necessary. The higher the voltage, the more penetrating are the rays, and they are said to be 'harder' in quality. Obviously, high-penetration rays will not be absorbed as much as those of low penetrating power.

A very important consideration is the choice of a setting which will give enough soft-tissue detail to outline the organs, thus rendering the plate more intelligible. If too high penetration is used, the plate lacks contrast and does not show the outline of the organs adequately. Better results are obtained by using as low a spark gap as is possible. A good method of determining the proper setting is that of exposing four plates, using a different spark gap for each. When the plates are developed, it is usually easy to choose the one that most nearly approximates the correct setting. Then, by a slight correction of this approximate setting, it is possible to obtain one which will give the desired result.

After setting the machine, the specimen is arranged on the plate (which is protected from ordinary light by two light-proof envelopes) according to the aspect to be photographed and the particular structures desired. The usual method is that of placing the animal upon its back and carefully spreading out the gills and viscera so as to obviate unnecessary superposition.

The tube must then be placed at the proper distance from the plate and accurately centered so as to cast the shadow in the center of the plate and so that the whole plate will be exposed. The central ray should strike the center of the plate at a right angle to the surface of the plate. This is followed by the simple operation of exposing the plate.

STEREOSCOPIC EXPOSURES

Plates secured in the way mentioned above offered a good picture of the blood system of *Necturus*, but with the serious objection that the parts photographed were all in one plane. This renders interpretation very difficult for those unskilled in reading x-ray plates and leaves one in doubt, often, as to the accuracy of his observations. The difficulties encountered are such as an attempt to determine the relative position of two vessels which cross or the location of a vessel in its relation to the body walls or viscera. This difficulty is somewhat obviated by photographing an animal in two different aspects representing two different planes which would give some idea of the depth of the vessels. This method was found rather clumsy and inaccurate for any except the larger vessels. With a view to obviating such difficulties, some experiments were made with stereoscopic exposures, thus bringing into the picture the element of the third dimension. This shows the blood-vessels as well as other parts in their proper relative positions.

In brief, this method consists of taking an exposure of the specimen, shifting the tube $2\frac{1}{2}$ inches and making another exposure on another plate. The specimen must not move between the exposures. Each plate represents what each eye would see if the eyes were at the positions the x-ray tube is during the two exposures. When these plates are viewed through the stereoscope their virtual images are superimposed and we see the object in three dimensions, and the plates are said to show stereoscopic relief.

For taking these stereoscopic exposures a special piece of apparatus is used, a stereoscopic plate-slide tunnel (fig .1). The photographic plate-holder which accommodates an 8 x 10 inch

plate (A) slides underneath a glass or celluloid plate (fig. 1, B) on which the specimen is spread out for exposure. Thus the rays pass through the specimen (fig. 1, C), then through the glass plate, and then strike the photographic plate. The glass or celluloid plate is one-half the size of the photographic plate. On each of two opposite sides of this glass there is a piece of sheet lead (fig. 1, D) equal in size to one-half of the photographic plate. When the plate-holder is pushed half way in, one half the photographic plate is covered with lead, thus protecting it from the rays, and the other half is under celluloid plate and is therefore in position for exposure (fig. 1, B). Then, when the plate-holder slide is pushed in full length, the part that has been exposed is now covered with lead, hence being protected, the other half that was covered with lead is now under the glass on which the specimen lies and is in position for the second exposure. The specimen has not moved, since it rests upon the glass plate and, therefore, is not in direct contact with the plate-holder.

If a makeshift apparatus is set up (which can easily be done), it is well to have the distance between the specimen and the plate as small as possible so as not to lose any detail. Direct contact between the specimen and the plate is always desirable when possible, because it gives better detail.

The specimen is spread out on the glass plate referred to in the description of the plate-slide tunnel. It should be placed as nearly in the center of the glass as possible. Since the stereoscopic exposures give the relative position of organs, it is better not to spread out the viscera, but to leave them in their normal position. The gills should be spread out as before.

The next operation is to accurately 'center' the specimen under the tube (fig. 1) by moving either the tube or the plate-slide tunnel. The specimen must remain as placed on the glass plate. The plate-slide tunnel is then moved $1\frac{1}{4}$ inches to the left in a line at right angles to the long axis of the specimen. The plate is placed in the plate-holder in such a position that half the plate will be exposed. After the first exposure is taken the plate-holder is pushed in so that the unexposed half of the plate will be under the specimen, the whole slide tunnel is shifted $2\frac{1}{2}$ inches to the right, and the second exposure made.

STEREOGRAPHS

Prints were made from the plates thus obtained upon F hard X Glossy Azo or as transparencies on Seed Process Plates. The latter gave far more satisfactory results, for when the transparency is placed in the stereoscope it is as though the eyes were at the target of the x-ray tube and looking through the specimen. A much better stereoscopic effect is obtained by looking at a transparency than at an ordinary print.

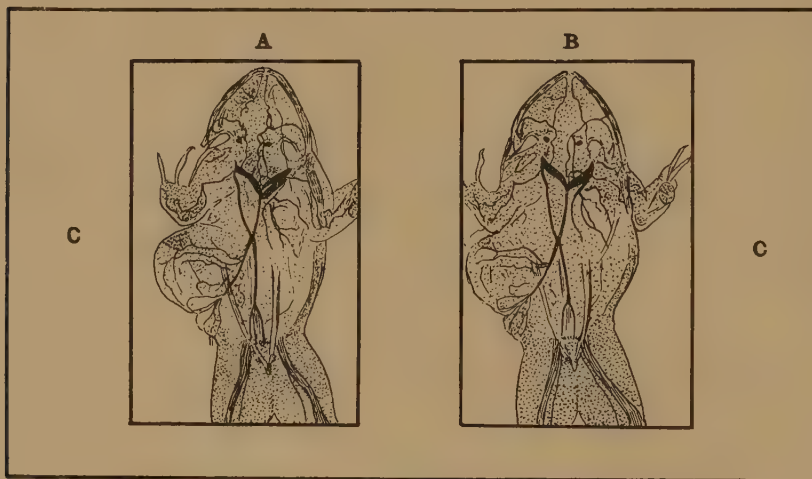


Fig. 2 Diagram of stereoscopic transparency. A and B. The two stereoscopic exposures placed so that their centers are $2\frac{1}{2}$ inches apart. C. Glass plates between which are placed the transparencies. The plates are held together by means of lantern-slide binding type.

When prints were made upon paper they were mounted upon sheets of cardboard 7 inches long and 4 inches wide. The same parts in each exposure should be on the same level or the images will not superimpose and the stereoscopic effect will be lost. The prints should be so mounted that their centers will be from $2\frac{1}{2}$ to 3 inches apart.

The transparencies are placed the proper distance apart ($2\frac{1}{2}$ inches), and mounted between 4x7 inch glass plates (fig. 2). To hold the transparencies in their proper position, the cover-plates are fastened together with lantern-slide binding tape.

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PLATE 1

EXPLANATION OF FIGURES

Arteries injected with barium sulphate and exposures made stereoscopic.
To better illustrate the possibilities of this method in studying the circulatory system of lower vertebrates remove the plate by cutting along the dotted line and place it in an ordinary stereoscope.

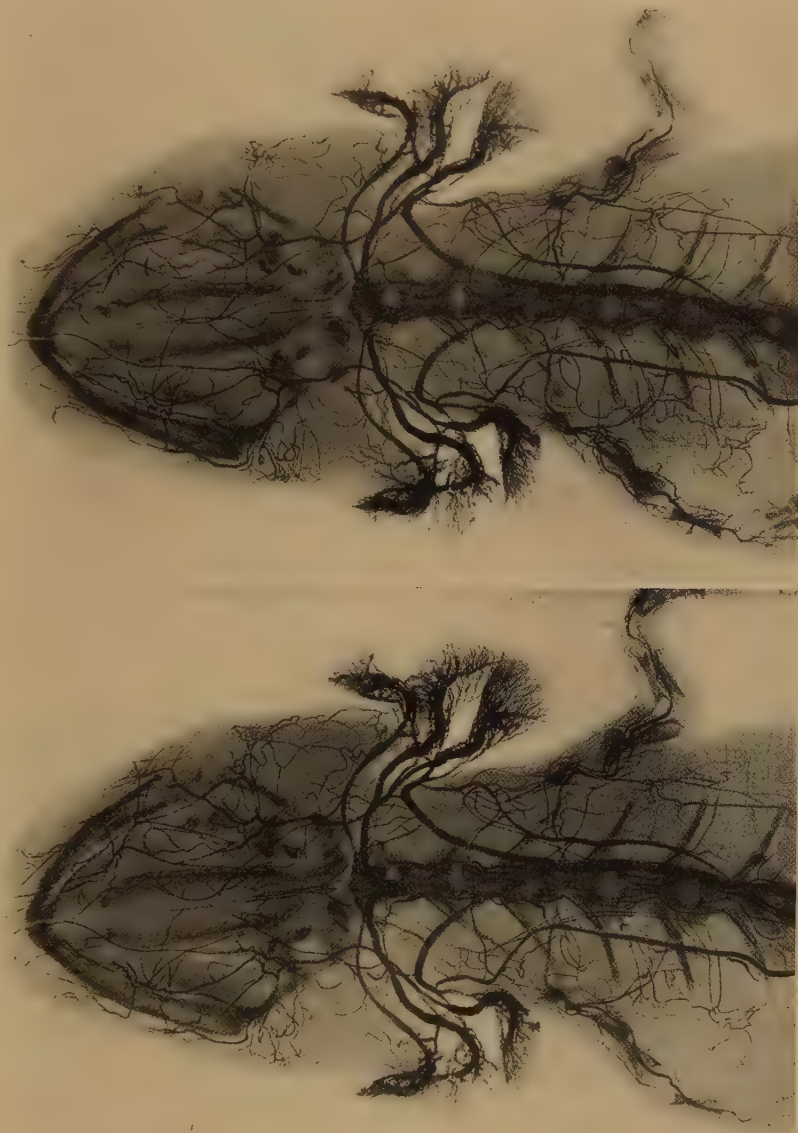
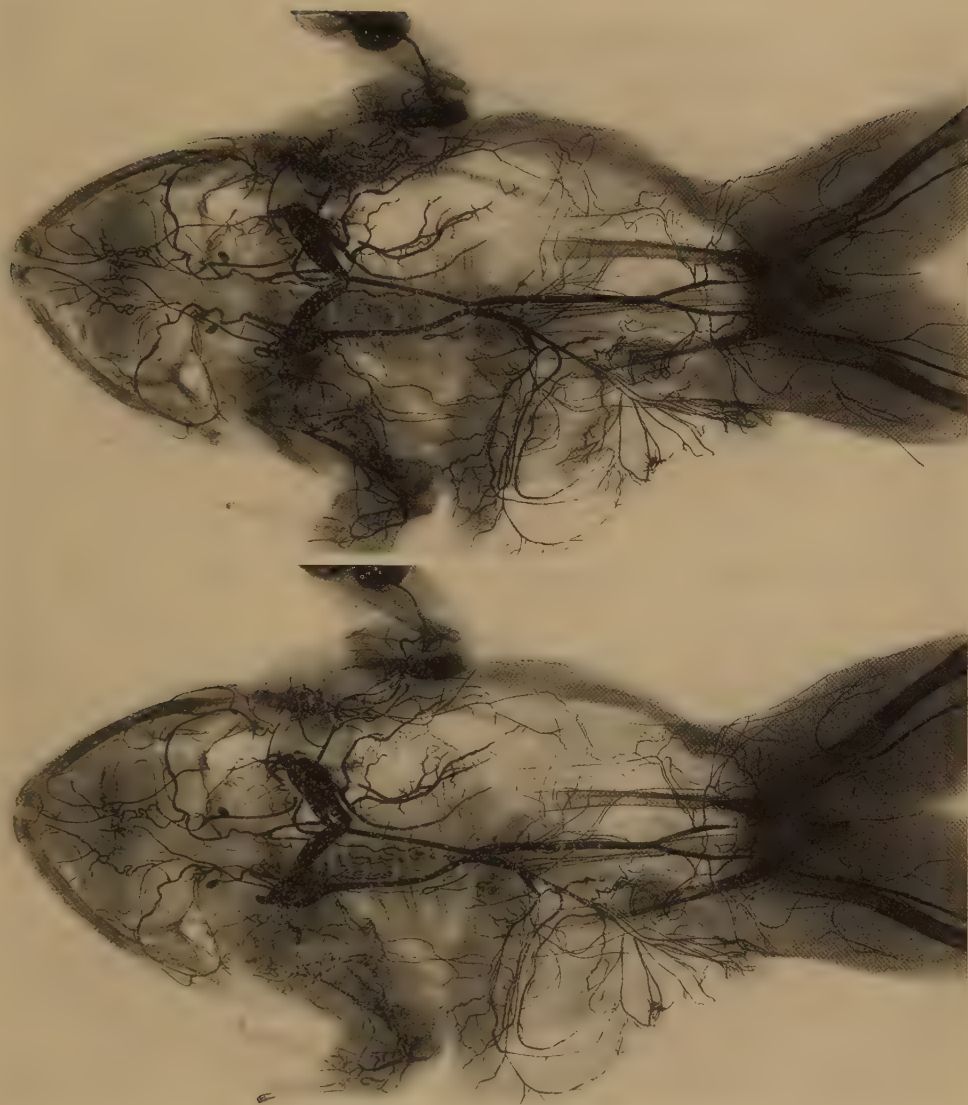


PLATE 2

EXPLANATION OF FIGURES

The common bullfrog. Arteries injected with barium sulphate. Remove the plate by cutting along the dotted lines. It may then be studied in a stereoscope. The abdominal cavity was opened and the viscera pulled to one side.



Resumen por el autor, John E. Sutton,
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Las fascias de la órbita humana.

Todas las estructuras situadas en la cavidad orbitaria están rodeadas por las fascias orbitarias. El globo ocular está rodeado por la fascia del bulbo; los músculos están rodeados y aglomerados por la fascia muscular y la grasa orbitaria está dividida en lóbulos mediante tractos fasciales. Las relaciones fasciales de todos los músculos rectos son conformes al tipo. La fascia de la superficie interna es continúa con la del bulbo; la que cubre a la superficie externa pasa al borde orbitario y al fornix de la conjuntiva. En conexión con cada uno de los músculos existen modificaciones especiales de las fascias, formando los ligamentos suspensores medio y laterales en los rectos medio y lateral, el ligamento suspensor superior en el elevador superior de los párpados y el recto superior; el ligamento suspensor de Lockwood en el recto y oblicuo inferiores. La inserción de la fascia del músculo oblicuo tiene lugar mediante pequeñas hojas fasciales producidas a expensas de la fascia muscular, a cada lado de la troclea. La fascia del músculo oblicuo superior atraviesa la troclea junto con el tendón. Cuando se analiza la fascia del músculo oblicuo superior puede comprobarse que sigue un plan de disposición que no difiere en detalle esencial alguno de la disposición de las fascias que rodean a los músculos rectos. La fascia que cubre a la superficie interna del músculo se une con la del bulbo y la cubierta externa pasa al borde orbitario y al fornix de la conjuntiva.

THE FASCIA OF THE HUMAN ORBIT¹

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SIX FIGURES AND ONE PHOTOGRAPH

INTRODUCTION

The anatomy of the human orbit and of the eye has long been the object of thorough researches. The works of Motais, Virchow, and others leave little further to be desired. In view of the extensive literature on the subject, it may seem presumptuous to attempt any addition to our knowledge of the fascia of the human orbit. There are, however, points in connection with the fascia of the superior oblique muscle and its relations to the trochlea which deserve further attention.

Tenon (1806) first described the fascia, calling it "une nouvelle tunique de l'oeil." It is "common to the globe of the eye, the optic nerve, and the lids. It serves most for the suspension of the globe in front at the entrance of the orbit and to bind it to the lids. At either angle of the orbit expansions pass out to give attachment to the bony margins. In front it passes out from the globe into the lids and extends under the conjunctiva as far as the tarsal cartilages." This tunic has since that time, been known as the capsule of Tenon. According to Motais, it is found in all animals which possess the power to move the eyes.

MATERIALS AND METHODS

In tracing the fascia of the orbit, the eyes of adults and children (ages, estimated, a few weeks to $1\frac{1}{2}$ to 2 years) were used. Although the check ligaments of the infant's eyes are not as

¹ From a thesis presented to the Faculty of the Graduate School of Cornell University for the degree of Master of Arts. June, 1917.

strongly developed as those of the adult's, the fascia is found in the same typical arrangement. The thinness of the bones of the skull and of the orbit facilitates their removal. The bony walls of the orbit may be removed without displacing any of the orbital contents. The adult specimens are to be preferred on account of the full development of all structures.

A gross dissection of the orbit and its contents is merely sufficient for gaining an elementary knowledge of the fascia. In this series of investigations, gross dissections, free-hand, and microscopic sections were used. The free-hand sections were cut with a large amputating knife and mounted on pieces of cork of convenient size. Under the dissecting microscope the fascia of these specimens was traced with considerable ease. The fascia in the freshly cut specimens was distinctly visible, and this distinctness has been retained in the formalin used as a preservative. In most cases it was unnecessary to disturb any of the tissue. The point of a needle, in some instances, served as a convenient instrument for separating fibers and fiber bundles which were not at first clearly and easily traceable.

In the study of the free-hand sections sudan III, followed by methylene or anilin blue, was used to advantage. After such treatment the fat is stained red, while the connective tissue has a bluish color. The stains were used to obtain only a moderate degree of coloring. These preparations were especially helpful in tracing the finer strands of the fascia.

The microscopic sections were cut from celloidin blocks. The bony orbits and contents, after first having been removed from the body, were carried through in toto. Subsequent staining for connective tissue accomplished the desired results.

THE FASCIA OF THE ORBIT

All structures in the orbit are enclosed in the orbital fascia. The globe of the eye is surrounded by its fascia, the fascia bulbi or the capsule of Tenon. The muscles are covered and bound together by the muscular fascia. The orbital fat is divided into lobules by strands of connective tissue. Although described separately, these fascia are all continuous with each other.

For description it is convenient to consider the fascia in relation with the structures which it covers. There are two divisions which one naturally chooses, the fascia bulbi surrounding the globe of the eye and the muscular fascia which is found in relation with the muscles.

THE FASCIA BULBI OR THE CAPSULE OF TENON

In the fresh subject the fascia bulbi (fig. 2, *a*) is seen as a glistening white membrane which extends from the entrance of the optic nerve anteriorly to a point past the equator of the globe. It encloses the posterior two-thirds of the eye and forms a socket in which it rests. Externally it is in relation with the orbital fat (fig. 2, *b*). Its internal surface covers the sclera (fig. 2, *c*). Posteriorly around the entrance of the optic nerve, where it is attached to the sclera, it is thin and delicate; but as it is traced anteriorly, it is found to become thicker and tougher. Just anterior to the equator of the globe the fascia becomes continuous with the muscular fascia (fig. 4, *a*) with which it passes to the fornix of the conjunctiva (fig. 4, *b*). Here it unites with the tunica propria of that membrane. Through the tunica propria of the conjunctiva the fascia finds attachment to the tarsal carilages (fig. 2, *e*) and the globe of the eye at the corneoscleral junction (fig. 5, *c*).

Many modern texts hold that the fascia bulbi forms a socket in which the globe of the eye may rotate. After a consideration of the attachments of the fascia, it is difficult to conceive of much rotation taking place.

Schwalbe, describing the fascia bulbi, divides it into a visceral and a parietal layer. Of the two the parietal layer is the more conspicuous and the thicker. It is this part which is commonly described as the fascia bulbi or the capsule of Tenon. The visceral layer, which covers the sclera and the tendons of the muscles, is thin and delicate.

The space beneath the fascia bulbi (fig. 2, *g*) is known as the space of Tenon or the suprascleral lymph space of Schwalbe. Extending vertically and obliquely across this space are found

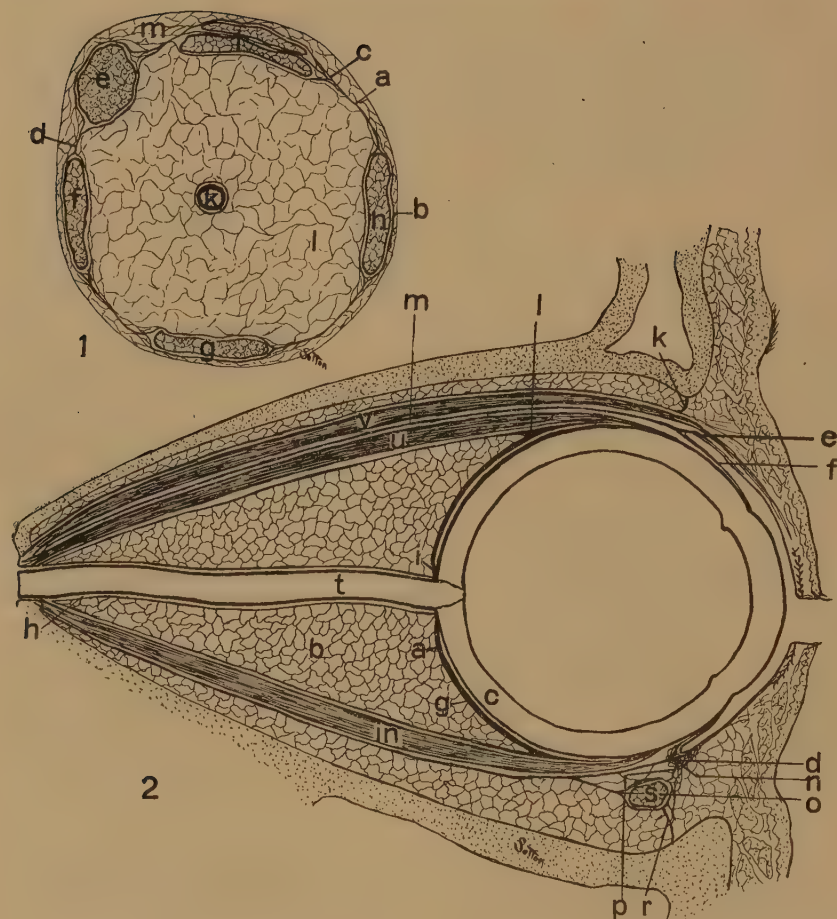


Fig. 1 Diagrammatic. Transection of the orbital contents dorsal to the globe of the eye. *a*, sheet of fascia between the lateral rectus and the superior rectus and the levator palpebrae superioris muscles; *b*, sheath of the lateral rectus muscle; *c*, union of the three sheets of fascia of the superior rectus and the levator palpebrae superioris muscles; *d*, sheet of fascia between the superior oblique and the medial rectus muscles; *e*, superior oblique muscle; *f*, median rectus muscle; *g*, inferior rectus muscle; *h*, lateral rectus muscle; *i*, levator palpebrae superioris and superior rectus muscles; *k*, optic nerve; *l*, orbital fat; *m*, fat external to muscular fascia.

Fig. 2 Diagrammatic. Median sagittal section through the contents of the orbit. *a*, fascia bulbi; *b*, orbital fat; *c*, sclera; *d*, suspensory ligament of Lockwood; *e*, fascia uniting at the fornix of the conjunctiva with the tunica propria of that membrane; *f*, union with the corneoscleral junction through the tunica

delicate connective-tissue fibers. "Lymph circulates freely in all parts of the space. By means of channels around the venae vorticosae the suprascleral space is in communication with the suprachoroidal space. Posteriorly the lymph passes into the supravaginal space (fig. 2, *h*) around the optic nerve" (Schwalbe). This space, in turn, is in connection with the subarachnoid space of the encephalon.

The suprascleral space is limited, anteriorly at the corneoscleral junction where the tunica propria of the conjunctiva is attached, and posteriorly around the entrance of the optic nerve (fig. 2, *i*) where the fascia is united to the sclera. Here are found communications with the supravaginal space (Schwalbe). Virchow, although he made no injections to follow the connections of the space, expresses his doubts as to the presence of such channels.

THE MUSCULAR FASCIA

The muscular fascia forms the sheaths for the extra-ocular muscles and stretches as a membrane between the adjacent margins of the muscles (fig. 1. *a*, *d*). In addition, the fascia gives off slips externally which pass to the bony margin of the orbit to form the orbital septum (fig. 2, *k*) and to the fornix of the conjunctiva (fig. 2, *e*). In certain regions of the orbital septum there are to be found local thickenings of the fascia which are known as check ligaments. Stretching as they do, from the external surfaces of the muscles to the margin of the bony orbit, they limit to a certain degree the movements of the eyeball.

propria of the bulbar conjunctiva; *g*, space of Tenon or the suprascleral lymph space of Schwalbe; *h*, supravaginal space; *i*, attachment of the fascia bulbi to the sclera; *k*, superior portion of the orbital septum; *l*, union of the muscular fascia with the fascia bulbi, thickened between the muscle and the sclera; *m*, muscular fascia between the superior rectus and the levator palpebrae superioris muscles; *n*, suspensory ligament of Lockwood; *o*, fascia from the inferior rectus which encloses the inferior oblique muscle; *p*, fascia from the inferior oblique which goes to the suspensory ligament of Lockwood and also helps to build the inferior portion of the orbital septum; *r*, inferior portion of the orbital septum; *s*, inferior oblique muscle; *t*, optic nerve; *u*, superior rectus muscle; *v*, levator palpebrae superioris muscle; *in.*, inferior rectus muscle.

The muscular fascia is easily demonstrated. The bony orbit and its contents are first removed from the head and all superfluous flesh and bone are cut away. The thin walls may then be removed up to the orbital margin. Here a thick ring of bone is left to facilitate handling and to keep the specimen intact. After the removal of the walls of the orbital cavity, the contents are seen as a conical mass, the base of which lies at the orbital margin. The periosteum, which is not removed with the bone, is next cut away. Underlying this is a thin layer of fat (fig. 1, *m*) which separates it from the muscles and the muscular fascia. A gross dissection shows the fascia to be thin posteriorly and thicker in its anterior portion. Both internally and externally the muscular fascia is united to strands of orbital fascia which separate the fat into lobules (fig. 1).

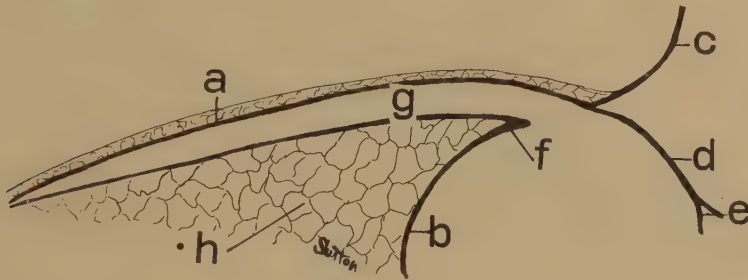
On reaching the tendons of the muscles the fascia follows two courses, an internal and an external. Internally it is reflected from the surfaces of the tendons backward to become continuous with the fascia bulbi (fig. 3, *f*); externally it passes to the fornix of the conjunctiva (fig. 3, *e*) and to the orbital margin (fig. 3, *c*). Internally, at the point where the muscular fascia and the fascia bulbi becomes continuous, there is a thickening (fig. 3, *f*) which serves as a pulley over which the recti muscles act. In the intervals between the muscles the fascia follows similar lines of reflection which, however, are not so well defined as in connection with the recti muscles (fig. 4).

The fascia which encloses the muscles has the shape of a thin tube or cone (fig. 3), which is open anteriorly where the tendon passes out and is closed at the apex where the muscle has its origin. In an examination of the lines of reflection of the fascia and a consideration of the investment of the muscles as cones of fascia, it is seen that neither the muscles nor their tendons pierce the fascia bulbi.

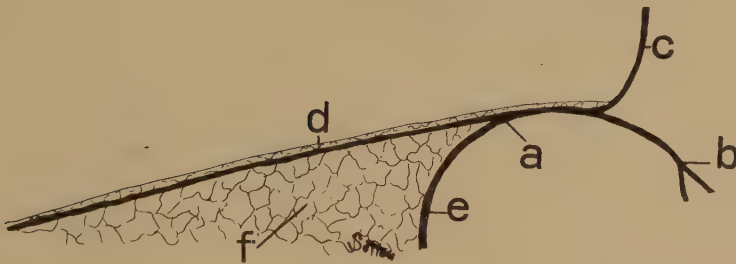
THE RECTI MUSCLES

The relations of the recti muscles are all of the same type; the fascia passes from the internal surface back to the fascia bulbi, and the fascia of the external surface finds attachment in

the fornix of the conjunctiva and on the orbital margin. There are certain modifications to be found in the relations of each muscle. The relations of the superior rectus are complicated by the presence of the levator palpebrae superioris. In connection with the medial and lateral recti are found the medial and lateral check ligaments. The inferior rectus comes into relation with the inferior oblique muscle and the suspensory ligament of Lockwood.



3



4

Fig. 3 Diagrammatic. Diagram of the fascia forming the sheath of one of the recti muscles. Reconstructed from dissections. *a*, fascia covering the external surface of the muscle; *b*, fascia bulbi; *c*, orbital septum; *d*, fascia continuing ventrally to unite with the tunica propria or the conjunctiva; *e*, fornix of the conjunctiva; *f*, union of the fascia bulbi and the muscular fascia with the thickened pulley-like structure; *g*, space for the muscle; *h*, orbital fat.

Fig. 4 Diagrammatic. Diagram of the fascia between two of the recti muscles. Reconstructed from dissections. *a*, union of the muscular fascia with the fascia bulbi; *b*, fornix of the conjunctiva; *c*, orbital septum; *d*, fascia between adjacent margins of muscles; *e*, fascia bulbi; *f*, orbital fat.

THE MEDIAL AND LATERAL RECTI MUSCLES

The general arrangement of the fascia is typical. In the sheets of fascia which are directed to the orbital margin are found thickenings to which have been given the names of medial

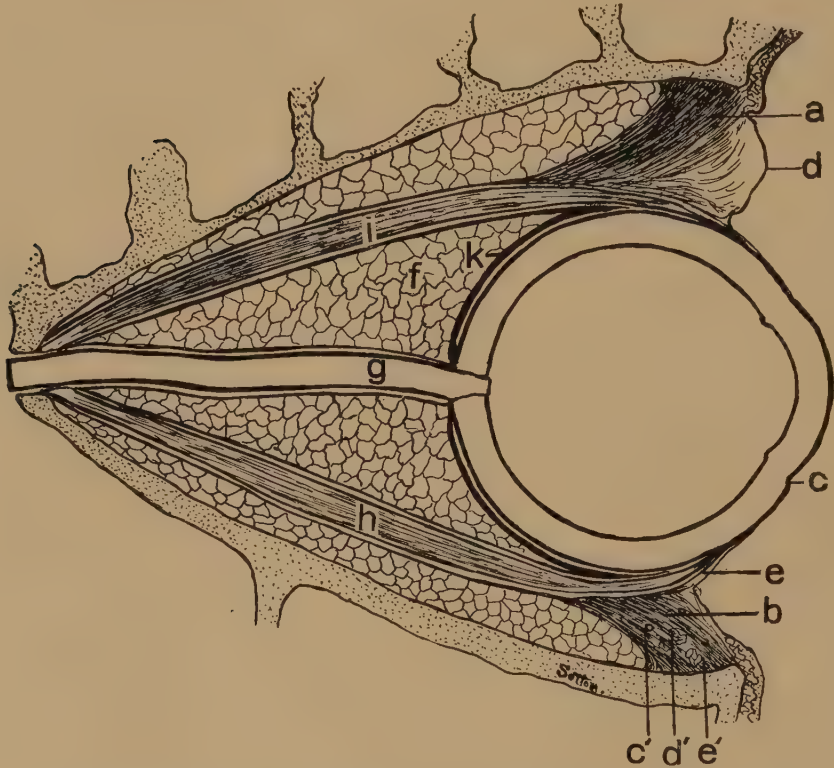


Fig. 5 Diagrammatic. Horizontal section through the medial and lateral recti muscles. *a*, medial check ligament; *b*, lateral check ligament; *c*, corneo-scleral junction; *d*, caruncula lachrymalis; *c'*, *d'*, *e'*, little veins, fat and lobules of the lachrymal gland; *f*, orbital fat; *g*, optic nerve; *h*, lateral rectus muscle; *i*, medial rectus muscle; *k*, fascia bulbi.

and lateral check ligaments (fig. 5, *a*, *b*). From the anterior sixth of the external surface of the muscles these condensations of fascia pass to their insertions on the margin of the orbit. They are roughly triangular in shape. The apices are directed

dorsally, in relation with the external surfaces of the muscles, while the bases look anteriorly.

Of the two check ligaments, the lateral or external is the better developed. It extends from the anterior extremity of the muscular belly of the lateral rectus muscle to the lateral angle of the orbit, where it is inserted on a line, 6 to 7 mm. long, dorsal to the lateral palpebral ligament. In general it follows the alignment of the muscle, forward and downward. Its greatest width is 6 to 8 mm. The distance from its orbital insertion to its union with the sheath of the muscle measures from 18 to 20 mm. The point of greatest thickness lies at a distance of from 3 to 6 mm. from the orbital insertion.

The ligament is not a dense structure, but is composed of a number of bundles of parallel fibers. These fasciculi are separated by small adipose masses, little veins, and lobules of the lachrymal gland (fig. 5, *c'*, *d'*, *e'*). In its posterior two thirds the structure corresponds closely to that of the muscular fascia, while in the anterior third plain muscle fibers have been found by Sappey and others.

The medial check ligament is of greater width (8 to 10 mm.); but its thickness (1 to 1.5 mm.) is less than that of the lateral ligament (Motais). It has a length of from 15 to 18 mm. as compared with a length of 18 to 20 mm. in the case of the lateral ligament. Covering the surface are many hair-like fibrous projections which unite with the capsules of the adipose masses in that region. There are no interstices similar to those found in the lateral check ligament. Its insertion lies along a line of 0.5 to 1 mm. in length on the superior half of the crista lachrymalis and dorsal to it for a distance of from 0.5 to 1 mm. along the frontoethmoidal suture. Similar to the lateral ligament, there are found plain muscle fibers in the anterior third.

There is no sharp line of demarcation between these thickenings and the adjoining parts of the orbital septum. Each becomes thinner toward the edge and finally fades out in the fascia. The predominating fibers are, according to Lockwood, elastic. Of the two ligaments the medial contains the greater proportion of elastic fibers (Motais).

THE SUPERIOR RECTUS AND THE LEVATOR PALPEBRAE
SUPERIORIS MUSCLES

The levator palpebrae superioris lies cephalad of the superior rectus muscle. True to type, the fascia of the internal surface of the superior rectus passes backward under the tendon to become continuous with the fascia bulbi (fig. 2, *l*). The fascia covering the external surface of the muscle lies between it and the levator palpebrae superioris. It is continued anteriorly to the fornix of the conjunctiva where it becomes continuous with the tunica propria of that membrane (fig. 2, *e*). The fascia covering the external surface of the levator palpebrae superioris muscle splits, just before it passes under the margin of the orbit, into two sheets. One enters the orbital septum (fig. 2, *k*), while the other accompanies the tendon of the muscle into the superior lid and is inserted with it into the tarsal cartilage and the surrounding tissue. On each side of these muscles the three layers of fascia fuse with each other and form a single membrane (fig. 1, *c*).

On either side of the tendon of the levator palpebrae superioris there is a small thickened band in the orbital septum. These, the superior check ligaments, are not very strongly developed.

THE SUPERIOR OBLIQUE MUSCLE

The passage of the tendon of the superior oblique muscle through the trochlea of necessity complicates the relations of its fascia. The arrangement is not, however, essentially different from that of the recti when the lamellae and their insertions are considered.

In the course of development the trochlea is a secondary structure. There is no connection between the muscle and the orbital wall in early foetal life. Gradually the developing muscle approaches the wall and finally becomes attached. In the early development the relations of the rudimentary fascia to the recti muscles and the superior oblique muscle must be the same. In the subsequent development these rudiments are carried with the superior oblique muscle to the trochlea through which they both pass.

The fascia covering this muscle is continuous on either side with the fascias of the medial rectus and of the superior rectus and the levator palpebrae superioris muscles (fig. 1). The fascia covering the external surface of the muscle and the anterior surface of the tendon divides into two lamellae. One extends to the orbital margin as a part of the orbital septum (fig. 6, *a*), while the other passes to the fascia bulbi around the globe of the eye

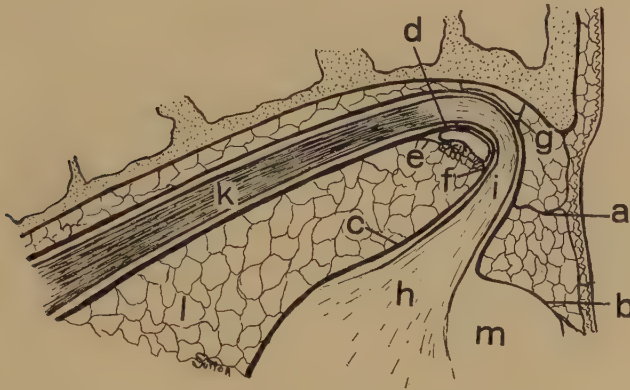


Fig. 6 a Diagrammatic. Showing the fascia and tendon of the superior oblique muscle passing through the trochlea. Reconstructed from dissections. *a*, orbital septum; *b*, fascia going to the fornix of the conjunctiva; *c*, fascia uniting with the fascia bulbi; *d*, fascia covering the internal surface of the muscle passing through the trochlea; *e*, slip of fascia given off by the fascia of the internal surface of the muscle which finds attachment at the dorsal border of the trochlea; *f*, same as *e*, but given off after the fascia has passed through the trochlea, directed dorsally; *g*, slip from the external fascia of the muscle given off after the fascia has passed through the trochlea; *h*, adnioniculum of the tendon of the superior oblique muscle; *i*, tendon of the superior oblique muscle; *k*, muscular belly of the superior oblique muscle; *l*, orbital fat.

(fig. 6, *b*) and is finally inserted into the fornix of the conjunctiva. The fascia covering the internal surface of the muscle and the posterior surface of the tendon becomes continuous with the fascia bulbi (fig. 6, *c*). The presence of the trochlea produces distortions, and the similarity between the arrangement of the fascia of the superior oblique muscle and that of the recti muscles may easily be overlooked.

The fascia accompanies the tendon through the trochlea (fig. 6). Modern texts describe a sheath of fascia which extends from the fascia bulbi to the trochlea, forming a tube in which the tendon of the muscle lies. This is in part correct. The attachment to the trochlea is, however, by small sheets of fascia given off by the muscular fascia which passes through the trochlea.



Fig. 6b The same explanation is used for the photograph as is used for figure 6 a.

The fascia covering the internal surface of the tendon and the muscle splits when it arrives at the dorsal border of the trochlea (fig. 6, *d*, *e*). The smaller sheet (*e*) becomes attached to the trochlea and the tissue surrounding it. The stronger sheet (*d*) passes on with the tendon of the muscle. Anterior to the trochlea another little lamella is given off which passes backward to the antero-inferior part of the trochlea and the adjacent tissue.

In connection with the fascia covering the external surface of the muscle and the anterior surface of the tendon, there are no slips given off until the entire fascia has passed through the trochlea (fig. 6). Anterior to the trochlea a lamella is given off which passes dorsally to unite with the superior part of the trochlea and the adjoining margin of the bony orbit (fig. 6, *g*). At a point about half way between the trochlea and the sclera this fascia splits into two lamellae, one of which helps to build the orbital septum (fig. 6, *a*), while the other passes to the fornix of the conjunctiva (fig. 6, *b*).

THE SUSPENSORY LIGAMENT OF LOCKWOOD

In the inferior part of the orbital septum is found another thickening of the fascia, the suspensory ligament of Lockwood. This bundle of fascia stretches like a sling between the lachrymal and the zygomatic bones. It lies inferior to the inferior fornix of the conjunctiva (fig. 2, *d*). At the center the fibers diverge to form a hammock-like structure upon which the globe of the eye rests. At this, its widest point, it is interwoven with the fibers of the fascia bulbi, but it does not lose its identity as a separate structure.

THE INFERIOR RECTUS MUSCLE

The sheath of the inferior rectus muscle and its relations conform to the plan of the other recti muscles. The reflection of the internal layer of the fascia shows no variation. From the external covering of the muscle there are given off small lamellae which unite with the sheath of the inferior oblique muscle (fig. 2, *s*) and the suspensory ligament of Lockwood (fig. 2, *d*). The characteristic sheet of fascia is sent to the inferior fornix of the conjunctiva. The lamella which unites with the sheath of the inferior oblique takes the place of the sheet which, in the cases of the other recti muscles, passes to the orbital septum by itself.

THE INFERIOR OBLIQUE MUSCLE

No direct comparison can be drawn between the relations of the inferior oblique muscle and those of the other extra-ocular muscles. At its origin it lies in the inferomedial portion of the orbital septum. As it passes laterally, dorsally, and cephalically, it is enclosed in fascia derived from the sheath of the inferior rectus, the orbital septum, and the web of the orbital cavity. In the interval between the lateral and the inferior recti muscles the inferior oblique muscle pierces the fascia bulbi to reach the sclera in which it is inserted.

The sheath of this muscle receives fibers from the sheath of the inferior rectus, the orbital septum, and the tissue web of the orbital cavity (vide supra and fig. 2).

THE FASCIA OF THE INTERMUSCULAR SPACE

The intermuscular space lies dorsal to the fascia bulbi which invests the globe of the eye, and is enclosed by the muscles and the muscular fascia. This space is filled with orbital fat (fig. 2, *b*, and fig. 5, *f*) in which the orbital nerves and vessels are embedded. The fat is divided into lobules by septa of connective tissue which are united to the muscular fascia and to the fascia bulbi.

Surrounding the optic nerve is a thin sheath of fascia forming the superficial boundary of the supravaginal space. Anteriorly this sheath of fascia is attached to the fascia bulbi around the entrance of the optic nerve. It comes into relation with the fascia at this point, but in the true sense of the word is not continuous with it. Dorsally the fascia extends to the annular tendinous ring from which the recti muscles, levator palpebrae superioris, and the superior oblique muscle have their origin. At this point it becomes continuous with the muscular fascia.

SUMMARY

With the exception of the facts regarding the fascia of the superior oblique muscle, the results of this investigation are merely duplications of the works of previous writers. The major facts

concerning the fascia of the human orbit have long since been firmly established. From the time Tenon described his "new tunic of the eye," in 1806, up to the present, much effort has been expended on the anatomy of the human orbit.

All structures lying in the orbital cavity are enclosed in orbital fascia. The globe of the eye is surrounded by the fascia bulbi; the muscles are enclosed and bound together by the muscular fascia, and the orbital fat is divided into lobules by strands of the orbital fascia.

The fascial relations of all of the recti muscles conform to the same type. The fascia of the internal surface becomes continuous with the fascia bulbi; the fascia covering the external surface passes to the orbital margin and to the fornix of the conjunctiva. In connection with each muscle are found special modifications of the fascia. The medial and lateral check ligaments are found in the fascia of the medial and lateral recti muscles; the levator palpebrae superioris and the superior rectus muscles are enclosed by means of three sheets of fascia, in connection with which are found the weakly developed superior check ligaments; the inferior oblique muscle comes into a varying relation with the orbital septum and the suspensory ligament of Lockwood; the superior oblique muscle with its fascia passes through the trochlea; and the relations of the inferior rectus are slightly affected by the presence of the inferior oblique muscle and the suspensory ligament of Lockwood.

The attachment of the fascia of the superior oblique muscle at the trochlea is by means of small sheets of fascia which are given off from the muscular fascia on either side of the trochlea. The fascia of the superior oblique muscle passes through the trochlea with the tendon. When analyzed, the fascia of the superior oblique is seen to follow a plan of arrangement which differs in no essential detail from the arrangement of the fascia which encloses the recti muscle. The fascia covering the internal surface of the muscle unites with the fascia bulbi; and the external covering passes to the orbital margin and to the fornix of the conjunctiva.

It is a pleasure to acknowledge the many helpful suggestions and courtesies extended by Dr. A. T. Kerr and other members of the medical faculty at Ithaca.

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Resumen por el autor, Augustus G. Pohlman,
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Consideraciones sobre los arcos branquiales del pollo, basadas en la persistencia anormal del cuarto arco izquierdo durante el estado de diez y seis días.

El ejemplar estudiado presenta persistencia del arco aórtico izquierdo, que desaparece normalmente al octavo día de incubación. El vaso anormal ocupa la misma posición relativa que la arteria normal del lado derecho y, descartando las diferencias de tamaño, ambos son de la misma longitud. El rudimento aórtico izquierdo se termina en la pared del conducto izquierdo al mismo nivel en que la luz de la aorta derecha comunica con la del conducto derecho. Próximamente dos tercios del conducto izquierdo están formados por el sexto arco y un tercio por la aorta dorsal. Los factores mecánicos que causan el aumento de longitud de los conductos son probablemente los mismos en ambos lados, a pesar del desarrollo del arco aórtico definitivo del lado derecho. El autor presenta un esquema modificado que sumará los datos sobre la desaparición de los segmentos branquiales, comentando lo imperfecto de la explicación que supone la existencia de crecimiento desigual y estancamiento de la sangre en la atrofia de ciertas porciones del sistema branquial.

Translation by José F. Nonidez
Carnegie Institution of Washington

A CONSIDERATION OF THE BRANCHIAL ARCADES IN CHICK BASED ON THE ANOMALOUS PERSISTENCE OF THE 4TH LEFT ARCH IN A SIXTEEN DAY STAGE

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THREE FIGURES

It has been the writer's experience that the interpretation of certain anomalies have contributed greatly towards a proper understanding of normal processes in the development. The value of such anomalies when properly worked out particularly those presenting persistence of structures which normally disappear at an early time, is to be found in the fact that they afford a direct clue to growth factors, and are in some instances, the only clue to such factors. The anomalous condition found in this sixteen day chick is in itself not of great moment, but when the metamorphosis of the branchial vessels and the establishment of definite trunks from these arteries and from the dorsal aortae is analyzed, certain deductions are permissible which may be regarded as contributions toward a more definite conception of the problem in general.

The usual diagrams of the transformation of the branchial system of vessels are, for the most part, based on the excellent work of Boas (1). The more recent investigations of Locy (2) and of Twining (3), following the injection and clearing technique of Mall, have demonstrated accurately the development and the disappearance of various segments of the aortic arches in the chick. The results of their investigations are succinctly stated by Lillie (4) in the following words: "Thus at the beginning of the fifth day the entire series of aortic arches has been formed, and the first, second, and fifth have entirely disappeared. The surviving arches are the third or carotid arch, the fourth or aortic

arch, and the sixth or pulmonary arch. Up to this time the development is symmetrical on both sides of the body. During the fifth and sixth days the two sides become asymmetrical, the fourth arch becoming reduced on the left side and enlarged on the right." "On the eighth day the changes indicated on the sixth day are completed. The left aortic arch has entirely disappeared, and the connection between the upper ends of the carotid and aortic arches is entirely lost on both sides, though lines of apparently degenerating cells can be seen between them. On the other hand, the upper end of the pulmonary arch (duct of Botallus) is as strongly developed on both sides as the right aortic arch itself. The pulmonary artery proper is relatively very minute and it can transmit only a small quantity of blood; the principal function of the pulmonary arch is obviously in connection with the systemic circulation." "The primary subclavian artery arises on the fourth day from the fifteenth (eighteenth of the entire series) segmental artery of the body wall when the wing bud forms, and gradually increases in importance with the growth of the wing. During the fifth day a small artery that arises from the base of the carotid arch grows backwards and unites with the primary subclavian at the root of the wing." "As the latter grows in importance the primary root dwindles and finally disappears (about the ninth day)." "The stem of the external carotid forms an anastomosis with the internal carotid in the mandibular region, and then disappears (8th day) so that its branches appear secondarily as branches of the internal carotid. The common carotid (*car. communis*) is derived entirely from the proximal part of the internal carotid."

When the diagram presented by Lillie after Boas (fig. 1) is studied in connection with the foregoing description, it will be seen that while an attempt is made to show the segments which normally disappear, no note is made of the atrophy in the external carotid stem; the peculiar behavior of the subclavian in relation secondarily with the internal carotid is omitted; the minor diagrammatical error of transposing the position of aorta and pulmonary stems has not been corrected; and finally, on both sides, a relatively long dorsal aorta and a short ductus segment is figured.

A corrected diagram, presenting fewer schematic errors, is suggested in fig. 1a which includes the time of disappearance of various segments; the subclavian vessels; and perhaps a better conception of the dorsal aorta in its relation to the ductus, particularly on the left.

It was thought important, in attempting to determine the causal factors in the closure of the double ductus system in the

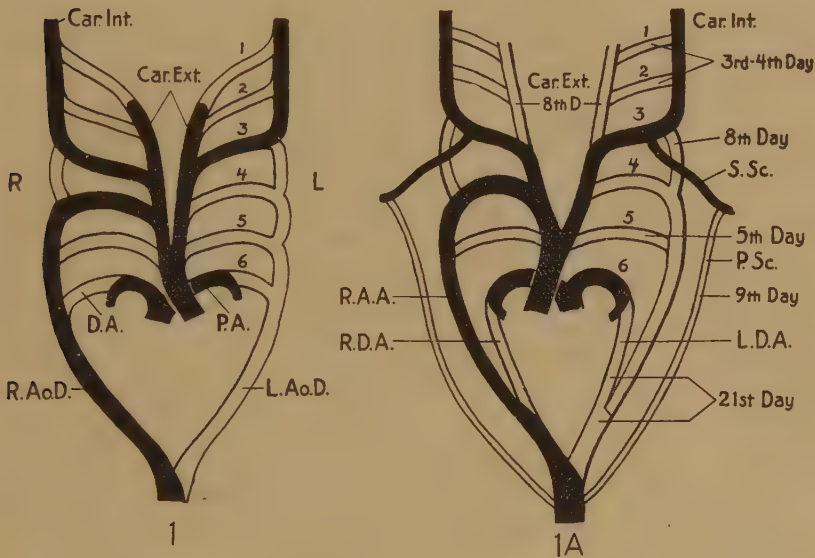


Fig. 1 Schematic figure of the aortic arches and their fate after Boas-Lillie.

Fig. 1A Modified scheme showing the date of disappearance of the various segments, including the primary subclavian artery (*P.Sc.*) and the secondary subclavian artery (*S.Sc.*).

bird at the time of hatching, to establish if possible the contribution of the dorsal aortae to the stem of the aortic arch and ductus on the right when compared with the single vessel on the left. Very little definite information on this point could be found and indeed the statement made by Hochstetter (5) is nothing more than an interpretation of the diagrams as they are usually presented: "This disappearance of the fourth aortic arch, however, results in the following condition; the left dorsal aorta, in so far

as it may persist, forms the continuation of the left ductus arteriosus Botalli and affords a secondary prolongation to this vessel."

The problem may be stated in a few words: How much does the left dorsal aorta contribute to the ductus arteriosus to form the single vessel on the left? The answer to this question is imperative if we are to consider mechanical factors which may play a part before and after the establishment of respiration on the one hand; and the histological behavior of the two segments of the vessel on the left on the other hand, because on the right only the ductus segment is affected while on the left both ductus and dorsal aorta respond.

Reconstruction models of this region in chicks of 16, 18, 20 and 21 days of incubation were undertaken with the idea of attempting the solution of this problem by measurements before going on with the older stages in which the ducti are closed. The writer realized in doing this that comparative measurements even under the most satisfactory conditions may not be productive of results because once the fourth arch on the left has disappeared completely, the point of original confluence of left dorsal aorta and ductus becomes arbitrary. Second, it would be impossible without some guide to assist in measurement, to determine whether or not the mechanical growth factor on the two sides was the same. One would assume this is not the case because of the progressive development of the permanent aortic arch on the right.

One sixteen day chick of the series displayed an interesting anomaly in a persistence of the fourth left arch which normally disappears on the eighth day. This specimen demonstrated quite accurately the very point sought and was deemed better evidence than any series of reconstruction models. Accordingly this brief report is offered.

The series was cut at 50 microns and stained in resorcin-fuchsin. A diagrammatic level reconstruction is shown in fig. 2 which presents the relations, accurate only in the vertical, of slides 5, 6, 7, and 8 of this embryo. The levels at which the sections are selected are shown against the figure number of the left. The micron interval between these sections is given in hundreds. The

forked vessel at the top of the figure is the bifurcation of the so-called common carotid into the internal carotid and subclavian; not internal and external carotid as one might assume.

Disregarding the size of the right aortic arch and the shifting of the pulmonary to the left of the aorta, the diagram presents a remarkably symmetrical form. The anomalous vessel on the

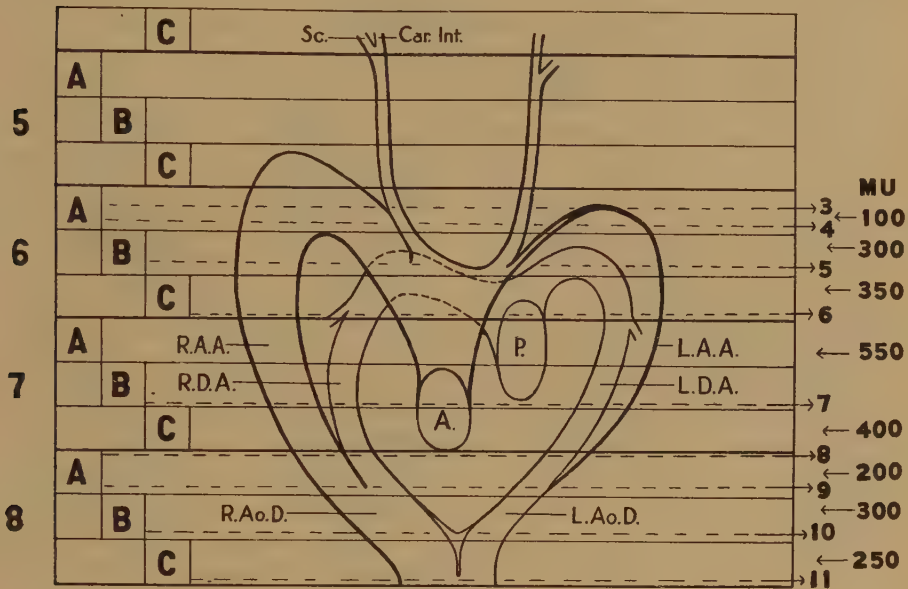


Fig. 2 Level reconstruction of the relations in the anomalous sixteen day chick ($\times 20$ diameters in the vertical). The figures on the left indicate the slide number in the series and the letter the section row. The figures 3-11 inclusive refer to the sketches in fig. 3 and show their relation. The section intervals are given in microns.

left practically coincides in every detail with the large right aortic arch, and most important, although the vessel is reduced to a cord of elastic fibres the left aorta terminates in the wall of the left ductus at the level at which the lumina of the right aorta and ductus become confluent. The length of the ductus on both sides is practically 1.1 mm. while the dorsal aorta segment on both sides measures 0.5 mm. In other words, it is fairly safe to assume that



Fig. 3 Sketches of the sections in the series at the levels indicated in fig. 2 ($\times 10$ diameters).

the measured value of the dorsal aorta on the right will correspond to that on the left in those cases where no guide persists to indicate in the single left vessel how much is dorsal aorta and how much is ductus proper. It would also appear that the displacement factors on the two sides are about the same and not greater on the left than on the right as one would anticipate from the massive development of the right aortic arch. .

It would be difficult indeed to account for the normal atrophy of the left aortic arch on the basis of growth-displacement and stagnation of blood current. Perhaps after all the active agent in causing a disappearance of the segments of branchial vessels may not be determined with the methods and facilities of the present day. No clue is offered in this specimen as to the amount of contribution which the right dorsal aorta affords to the right aortic arch.

In conclusion the case shows a persistent left aortic arch in a sixteen day chick which indicates that the amount of contribution of the dorsal aorta on the right to the aorta and ductus is the same as that of the corresponding vessel on the left; in this case equal to one half the ductus length. Second, the position and relation of the anomalous vessel appears to demonstrate that the growth-displacement factors of the two sides are about the same in spite of the normal massive development of the right aortic arch. Finally with a more or less definite separation of the left vessel it is possible to study histologically the structure of the two dorsal aortae and to determine whether or not structural differences are responsible for the atrophy after hatching of the dorsal aorta on the left. It is probable that the investigation in the bird may offer an explanation of the closure of the ductus in the mammal where the problem is made more difficult because a check vessel is wanting.

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Un caso de desplazamiento cruzado del riñón con fusión.

El riñón izquierdo está desplazado hacia el lado derecho, y su polo superior está fusionado con el inferior del riñón derecho. El uréter del riñón derecho sigue prácticamente su curso normal. El del riñón desplazado pasa hacia la izquierda por detrás del colon pélvico y la arteria hemorroidal superior, entrando en la vejiga por el lado derecho. Los vasos del riñón derecho no presentan caracteres anormales. El riñón desplazado está irrigado por dos arterias, una que nace de la aorta, prácticamente en común con la arteria mesentérica inferior; la segunda arteria fué cortada durante la disección sin poder determinar exactamente su origen. Del riñón desplazado parten dos venas, de las cuales la mas pequeña e inferior es tributaria de la vena cava inferior, en el comienzo de esta última; la vena superior y mas grande tuerce hacia la izquierda por debajo de la arteria mesentérica inferior, pasando hacia arriba para desembocar en la vena cava en el sitio de costumbre. La longitud es de 12.5 cm. Esta vena probablemente está formada en parte por una sección persistente de la vena cardinal posterior izquierda, situada entre el punto de entrada de una vena renal anormalmente baja y la anastomosis que reúne las venas cardinales y subcardinales. Ambas glándulas suprarrenales estaban situadas normalmente.

Translation by José F. Nonidez
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A CASE OF CROSSED DISPLACEMENT OF THE LEFT KIDNEY WITH FUSION

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TWO FIGURES

ANATOMICAL DESCRIPTION

1. Position of the Kidneys

The left kidney is displaced to the right side and lies inferior to the right kidney. The right kidney is abnormally low, its lower pole overlapping the crest of the ilium and extending about 2.5 cms. below it. The upper pole of the displaced left kidney is on about the level of the iliac crest, medial to the lower pole of the right kidney, while its lower pole extends down to the level of the fifth lumbar vertebrae and slightly overlaps the right common iliac artery. The medial extremity of the left kidney overlaps the Inferior Vena Cava, (fig. 1).

2. Size and Shape

a *Right Kidney.* Length: 8.75 cms. Circumference 12.5 cms.

b. *Left Kidney.* Length: 7.5 cms. Circumference: 15 cms.
Width: 6.9 cms. Thickness: 1.7 cms.

The right kidney is normally shaped and the hilus is directed medially. The left kidney is very much broadened in the coronal and flattened in the sagittal direction. It appears to be split open, with an extremely large hilus on the anterior surface, which extends practically from the upper to the lower pole and its greatest width, which is at the middle, is about 2.1 cms. On account of the extreme thinness of the kidney and the large hilus, the sinus is very shallow and practically wide open on the surface. The

hilus and sinus divide the anterior surface of the kidney into two distinct parts, the lateral division being semilunar in shape with the concavity directed medially, while the medial portion is somewhat quadrangular shaped, being 2.8 cms. wide and 5.6 cms. long. On the anterior surface these two parts appear to be entirely

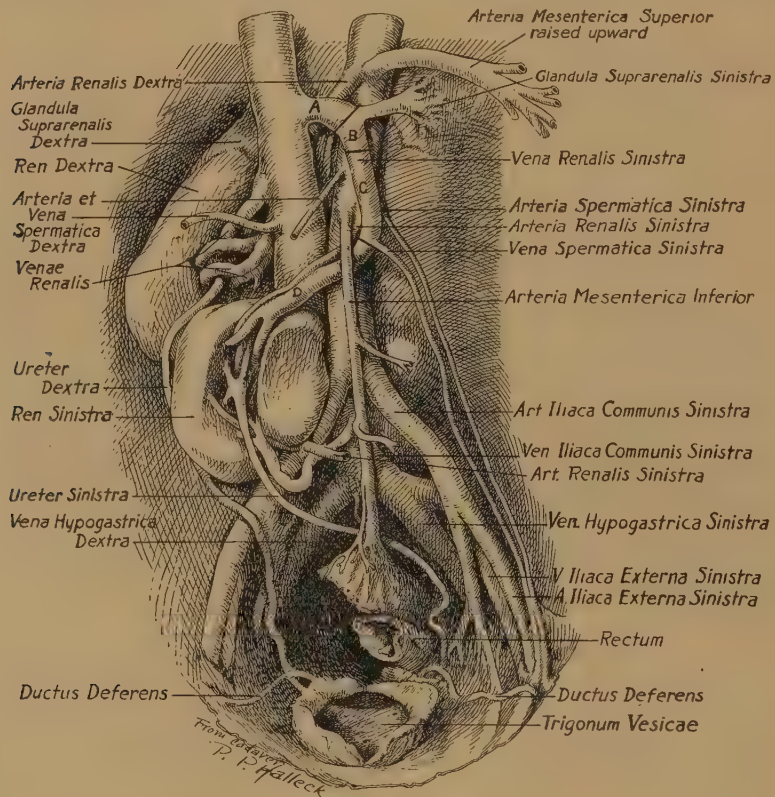


Figure 1

separate from each other, but on the posterior aspect, which is flat and very smooth, there is no sign of any demarcation between them.

3. Vessels of the Right Kidney

a) *Arteries.* A single artery is given off from the aorta which passes downwards and laterally, posterior to the Inferior Vena

Cava, at the lateral extremity of which, it bifurcates into two large terminal branches. The smaller and most anterior of these branches passes between the two upper and the two lower renal veins and anterior to the pelvis of the ureter, it then enters the hilus at its extreme ventral limit. Just as it sinks into the sinus it breaks up into one large and one small terminal branch. The larger and more posterior terminal branch of the renal artery enters the hilus near its upper limit, deep to all the other structures, and also gives off a small branch which passes between the two upper renal veins and enters the upper and ventral limit of the hilus.

b) *Veins*. Four rather large veins emerge from the hilus, which can be classified into an upper and a lower pair. The two upper veins, between which the last mentioned small artery passes, soon unite to form a large vein which passes upwards and medially, anterior and parallel to the right renal artery, to enter the Inferior Vena Cava. The smaller of the lower pair of veins emerges from the hilus with the first branch of the renal artery described, and then passes upwards and medially, parallel to that artery and anterior to the ureter, to enter the Inferior Vena Cava. The second of the lower pair of veins, the largest of the four, is deeply placed and emerges posterior to the ureter, it then passes upwards, posterior and parallel to its mate, and the two enter the Inferior Vena Cava practically by a common orifice.

4. Vessels of the Displaced Left Kidney

a) *Arteries*. There are two main arteries. The upper and larger one arises from the aorta on the same level and just to the left of the Inferior Mesenteric Artery. It then swings under the Inferior Mesenteric Artery and passes horizontally and to the right along the upper border of the displaced kidney. When it reaches the upper limit of the hilus it turns and passes downward along its lateral edge and sinks into the sinus at about the junction of the upper one-third with the lower two thirds of the lateral margin. Before it turns downwards, while it is still passing parallel to the upper border of the displaced kidney, it gives off

four branches, three of which are very short and immediately enter the upper part of the medial quadrangular division of the kidney. The fourth branch turns and passes downward along the medial margin of the hilus and enters the sinus on about the same level as the main branch. Therefore the upper one third or half of the hilus has an artery running along both its lateral and medial margin. The lower Left Renal Artery is much smaller. Unfortunately the student who dissected the body broke it, and I was unable to determine its exact origin, but from its relations it must have been a branch from one of three arteries; either the Right or Left Common Iliac or the Inferior Mesenteric. It passes to the right, anterior to the Right Common Iliac Artery, and at the lower margin of the left kidney gives off several small branches which enter the lower pole of the medial quadrangular portion; the main trunk then swings into the lower part of the hilus and passes upwards along the lower two-thirds of its lateral margin, where it enters the sinus. The margins of the hilus are, therefore, surrounded by arteries, with the exception of the lower medial two-thirds.

b) *Veins*. Are arranged in two sets: The two upper veins correspond to the arteries, one running along the lateral and the other along the medial margin of the hilus; the medial vein, however, has a longer course than the corresponding artery; it runs along the whole extent of the medial and also the lower part of the lateral margin of the hilus and has, therefore, a J shape. These two veins unite at the upper limit of the hilus to form a very large vein. The course of this vein is one of the most striking peculiarities of the specimen. It passes horizontally and medially and after *swinging under the Inferior Mesenteric Artery*, runs upward on top of the aorta, to about the level of the upper pole of the right kidney, where it turns to the right and enters the Inferior Vena Cava at about the normal level for the Left Renal Vein. Its total length is a little over 12.5 cms. While it is still on top of the aorta, just as it turns to the right to enter the Inferior Vena Cava, it receives the large left supra-renal vein, and just before it passes under the Inferior Mesenteric Artery, it receives the Left Internal Spermatic Vein. The smaller

and lower vein is made up at the inferior margin of the hilus and runs to the left with its companion artery, anterior to the Right Common Iliac Artery, to enter the beginning of the Inferior Vena Cava.

5. *Other Vessels*

The Inferior Vena Cava is formed lower than normal, at about 2.5 cms. below the bifurcation of the aorta, or at the upper part of the fifth lumbar vertebra.

The Right Hypogastric Vein instead of joining the Right External Iliac, enters the Left Common Iliac Vein; so that a Right Common Iliac Vein is not present.

The Left Supra-Renal Vein is very large, and is made up by a collection of small veins which emerge from the gland.

Spermatic arteries and veins are normal.

6. *Suprarenal Glands*

The Right Suprarenal has its normal relation to the upper pole of the Right Kidney. Left Suprarenal Gland is normally placed and is on about the same level as the right.

7. *Ureters*

a) *Right Ureter.* The ureter from the right kidney emerges from the hilus and swings downward and somewhat laterally in a shallow groove between the fused parts of the two kidneys, making a curve with the convexity directed upwards and laterally; it then turns downward and runs just under the lateral edge of the displaced kidney. Continuing downwards, it emerges from under the left kidney and crosses the Right Common Iliac Artery at its point of bifurcation and descends into the pelvis slightly antero-lateral to the Hypogastric Artery, finally entering the bladder in a perfectly normal manner. It is crossed by the Ductus deferens on the level of the spine of the ischium, and has the correct relation to the Seminal Vesicles.

b) *Ureter from the Displaced Left Kidney.* Four calyces unite to form a very small pelvis, which is exposed to the surface in the

shallow sinus. The ureter passes downwards leaving the sinus at the inferior pole of the kidney, and passing gradually to the left, it lies anterior to the Right Common Iliac Artery and the displaced Right Hypogastric Vein, and posterior to the lower part of the pelvic colon and the Superior Hemorrhoidal Artery. Still passing to the left and downward it comes to lie anterior to the Left Hypogastric Vein and medial to the artery, and then continues downwards to a perfectly normal entrance into the bladder on the left side. Its relation to the Ductus deferens is normal. The trigonum of the bladder is also normal.

DISCUSSION

This case probably represents one of the rarest of kidney anomalies. According to McMurrich, Birmingham states that Morris has seen it only once in 14,318 autopsies. McMurrich in reporting his case gives an excellent summary of all the cases reported up to that time. He cites in all just 28 cases, and states that only 26 of these can be considered as true examples of crossed dystopia.

Any attempt to fully explain the embryonic causes for this anomaly would, of course, be practically without foundation, considering the present nebulous state of our information on the subject, but certain interesting similarities in these cases have been pointed out. McMurrich states that in 83 per cent of cases, the ureter from the upper kidney opens into the right side of the bladder when the fused organ is on the right side, and into the left side of the bladder when the fused organ is on the left side. This means that in 83 per cent of cases the displaced kidney has been retarded in its upward migration. Just what this retardation may have to do with its subsequent displacement is hard to say, however, the time element, which is so prominent a factor in all embryonic activities, cannot be overlooked. When an organ has failed to migrate at the proper time it is at once subjected to the influence of adjacent organs, which under normal conditions, would not have affected it. In the case of a retarded kidney, at least three such foreign influences may play a part in its displace-

ment: first, the rotation of the gut when it begins to assume the adult position; second, the great increase in size of the caudal end of the Wolffian body, which would not affect a normal kidney because it would have already migrated towards the cranial end of this organ, which is already undergoing degeneration and decreasing in size; and thirdly, the descent of the sex gland.

In the present case we may safely state that the displacement occurred before the rotation of the intestine, because of the relation of the left ureter to the pelvic colon and the relation of the left Renal Vein and Artery to the Inferior Mesenteric Artery.

Jeidell, in his work on the vascularization of the kidney, has shown that in 14 mm. pig embryos, the Inferior Mesenteric Artery gives off what may be considered, as the main temporary artery to the growing kidney, and since the main artery to the displaced kidney in this case arises from the aorta practically in common with the Inferior Mesenteric, we may again roughly determine the time at which the displacement occurred. According to Jeidell's work, the Renal Veins at this same stage are tributaries of the Posterior Cardinal Veins.

The length and course of the Left Renal Vein can only be satisfactorily explained by considering the primitive venous system of this region and its later metamorphosis. The early veins to be considered are the two Posterior Cardinals, the two Subcardinals, and the Hepatic Veins, and the various anastomoses which take place between them. At its cranial limit each Posterior Cardinal joins the corresponding Anterior Cardinal to form the Ductus Cuvieri; while inferiorly each is made up by the union of the corresponding Internal and External Iliac Veins. In addition each Post. Cardinal receives the Mesonephric Veins; the temporary, and later the permanent, renal veins. The Subcardinals lie on the ventral surface of the mesonephros and each may be considered as being formed by a ventral anastomosis between the mesonephric tributaries of the Post. Cardinal; hence each Subcardinal joins the corresponding Post. Cardinal both cranially and caudally, while between these two limits there are many anastomoses between them. There are also many connections between the two Subcardinals across the aorta (fig. 2 A). The first im-

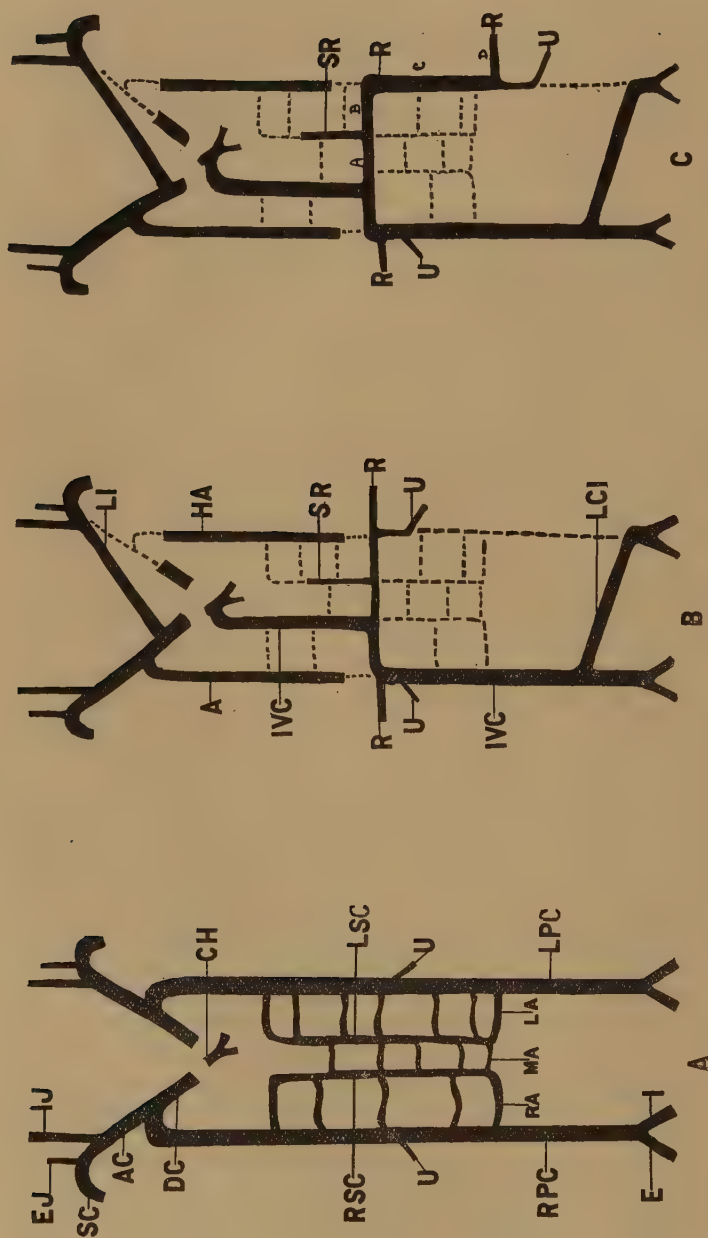


Fig. 2 A, B, C. E, External Iliac; I, Internal Iliac; RPC, Right Posterior Cardinal; LPC, Left Posterior Cardinal; RA, Anastomosis between Right Cardinal and Subcardinal; LA, Anastomosis between Left Cardinal and Subcardinal; MA, Anastomosis between right and left Subcardinals; RSC, Right Subcardinal; LSC, Left Subcardinal; CH, Common Hepatic; AC, Anterior Cardinal; IJ, Internal Jugular; EJ, External Jugular; SC, Subclavian; IVC, Inferior Vena Cava; R, Renal; U, Urinerve (Spermatic Vein); SR, Suprarenal; HA, Hemiazzygos; A, Azygos; LCI, Left Common Iliac; LI, Left Innominate; DC, Ductus Cuvieri.

portant change consists in an anastomosis between the cranial end of the Right Subcardinal and the Common Hepatic Vein in the caval mesentery, by which a new channel is established to the heart independent of the Ductus Cuvieri. Following this, the connecting trunk across mid-line between the two Subcardinals, which lies just caudal to the Superior Mesenteric Artery, begins to predominate over other similar trunks. On each side, and on the same level, one of the anastomoses, between the corresponding Cardinals and Subcardinals, also shows a similar enlargement. Thus a trunk is formed across mid line which connects these four veins at the level at which the future permanent renal veins join the Post. Cardinals. The third step consists in the formation of the Left Common Iliac, which connects the lower parts of the two Post. Cardinals. It is also necessary to call attention to a small vein, the "Urnierenvene" of Hochstetter, which enters the Post. Cardinal just below the level of the future permanent renal vein (fig. 2, A).

The final establishment of the adult condition consists in degeneration and loss of connections between certain of these veins. The segment of both Subcardinals below the transverse anastomosis, probably degenerates completely. The upper part of the left Subcardinal, according to Hochstetter, remains as the left Suprarenal Vein, fig. 2 B; while the upper portion of the right constitutes a part of the adult Inferior Vena Cava. The portion of the transverse anastomosis, which lies to the left of the Right Subcardinal, remains as a part of the Left Renal Vein. The 'Urnierenvene' remains as the Spermatic Vein, which, therefore, consists of the lower part of the Left Post. Cardinal, between the entrance of the Spermatic Vein and the Left Common Iliac, normally degenerates; while the lower part of the Right Posterior Cardinal remains as the lower portion of the Inferior Vena Cava (fig. 2 B). The upper parts of the Post. Cardinals, above the transverse anastomosis, lose their connections with the lower portions, and remain as the Azygos and Hemiazygos system.

Now, if we consider the left kidney to have been prevented from reaching its proper height, then instead of the left Renal

Vein going into the Left Posterior Cardinal at the level of the transverse anastomosis, it must have joined it some where below this point, and as this case shows, the Left Spermatic (Urnieren-vene) was also low, and entered the Left Post. Cardinal below the renal (fig. 2 C). Therefore, that portion of the Left Posterior Cardinal, between the transverse anastomosis and the entrance of the Left Renal Vein, did not degenerate, but remained as a part of the Left Renal Vein, and when the kidney was displaced this long vein was carried across the aorta and under the Inferior Mesenteric Artery (fig. 2 C).

If we consider that the upper segment of the Left Subcardinal remains as the Left Suprarenal Vein, then it is possible to divide the Left Renal Vein in this specimen into four parts: part A (fig. 1) lies between the Inferior Vena Cava and the entrance of the Left Suprarenal Vein, and is the remains of the original anastomosis between the Right and Left Subcardinals (fig. 2 C); Portion B (fig. 1) is not definitely separated, but extends for a short distance distal to the Left Suprarenal Vein, and is the remains of the anastomosis between the Left Cardinal and Subcardinal (fig. 2 C); portion C (fig. 1) and also a small part of the Internal Spermatic, consists of that portion of the Left Posterior Cardinal which extended between the transverse anastomosis and the entrance of the Renal Vein (fig. 2 C) and on account of the low position of the Renal Vein did not undergo the normal degeneration; portion D (fig. 1) which lies distal to the entrance of the Internal Spermatic, is the original short Renal Vein (fig. 2 C).

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Resumen por el autor, Charles Martell Wilhelmj,
Escuela Médica de la Universidad de San Luis.

Un caso de uréter doble en el hombre, coincidente con la falta de desarrollo del riñón en la inmediación del uréter aberrante.

El interés principal de este caso no estriba en la presencia del doble uréter, sino en la relación del uréter accesorio con la masa situada encima del riñón y la posición de los orificios de los dos uréteres en la vejiga. La masa en que termina el uréter aberrante está situada en la cara superior del riñón, fundiéndose medialmente con la cápsula y lateralmente con la corteza. Los cortes microscópicos de dicha masa demuestran que está compuesta de un substrato fibroso que contiene tres tipos de tubos atípicos y ningún glomérulo. Esto indica la posibilidad de que el uréter accesorio estuviese tan solo parcialmente incluido en el tejido nefrogénico que corona el uréter normal. Los dos uréteres desembocan en la vejiga mediante un orificio común; sus relaciones sin embargo, siguen la misma regla que la de los uréteres dobles completos, es decir, el uréter inferior se entrecruza con el superior en la parte lateral estando situado encima de él cuando ambos penetran en la vejiga. Esta torsión del orificio común tuvo lugar probablemente durante el desplazamiento hacia abajo de la pared posterior del seno urogenital, que separó los orificios del uréter y del conducto de Wolff.

Translation by José F. Nonidez
Carnegie Institution of Washington

A CASE OF DOUBLE URETER IN MAN WITH FAILURE OF DEVELOPMENT OF THE KIDNEY ABOUT THE ABERRANT URETER

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EIGHT FIGURES

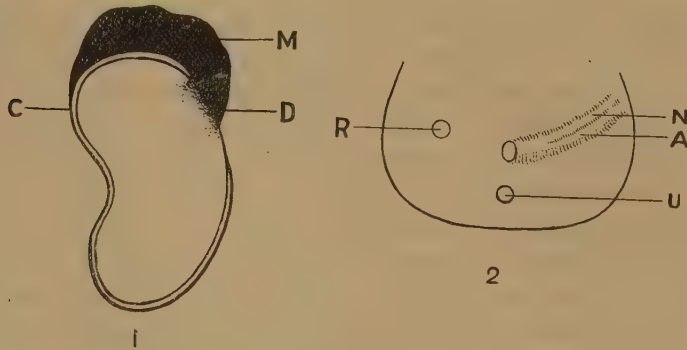
ANATOMICAL DESCRIPTION

Specimen was taken from a middle aged male. Clinical history unknown. Both kidneys normally placed. General course of the ureters and the relation of each to the corresponding Ductus deferens is normal. Right kidney much enlarged—length about 12.7 cm., circumference, greatest at the hilus, 19 cm.; from here it tapers rapidly toward both poles. Left kidney very small, length 7.6 cm.; greatest diameter 12.5 cm.

Right ureter and its manner of emergence from the hilus is normal. Two ureters apparently emerge from the left kidney. On closer examination, however, the ventral or upper ureter is found not to enter the kidney proper, but to go into a small ragged, fibrous mass of tissue located on the superior, posterior and medial aspect of the kidney, fig. 1 (M). This mass is free from the apex of the kidney, so that a probe can easily be passed between the two, but both the medial and lateral extremities of the mass become continuous with the kidney. The medial extremity apparently blends with the thickened capsule fig. 1 (c) while the lateral extremity becomes continuous with the kidney cortex fig. 1 (d). On the posterior aspect of this mass, posterior and above the point where the ureter fuses with it, there is a thin, sack-like structure. The ureter blends indistinctly with the body of the mass. The ureter from the left kidney proper is pervious throughout its entire length. The lumen of the aberrant ureter is open up to about 2.5 cm. before it enters the mass

where it is lost, its lumen also becomes extremely small at a point about 6.25 cm. above its opening into the bladder, but this constriction extends only for a distance of about 1 cm.

The right renal artery and vein are normal. The left renal artery arises from the aorta at the normal position and then divides into two terminal branches; one of these passes upwards into the interval between the mass and the kidney proper, giving a branch to the cortex as it ascends. The larger terminal branch passes downward and enters the hilus of the kidney posterior to the pelvis of the normal ureter. Several small veins emerge from the mass and unite with two branches from the kidney to form the renal vein.



Figures 1 and 2

The capsule of the left kidney peels off easily except near the upper pole where it is adherent, and apparently it passes between the mass and the kidney to blend with the under surface of the mass. Cut surface of the left kidney appears normal except for a short scar-like area which begins at the cortex, where the lateral extremity of the mass blends with it, and continues a short distance toward the sinus.

The aberrant ureter descends posterior to all of the vessels. The normal ureter emerges posterior to all of the vessels except the one branch of the posterior division of the renal artery, which enters the hilus posterior to it. As they descend the aberrant ureter lies ventro-medial to the normal ureter until within a very

short distance of where they enter the bladder wall, where the normal or dorsal ureter swings around the lateral side of the aberrant ureter and lies directly on top of it as they enter the bladder. (fig. 2 N and A). Maintaining this position they run obliquely forward and medially under the mucosa for about 1.8 cm., and open into a common channel of a little over 6 mm. in length, which terminates in the bladder almost directly posterior to the internal urethral orifice (fig. 2 U). As the ureters traverse the bladder wall under the mucosa, they give rise to a well marked cylindrical fold which seems to consist partly of the muscle wall. This might have been due to the state of contraction, but I am inclined to believe that it was present during life. The right ureter enters the bladder normally (fig. 2 R). The trigonum is, therefore, displaced as in figure 2, with the apex directed to the right.

The left spermatic artery is given off from the aorta just below the renals; passes upwards between the renal artery and vein, and finally hooks over the vein to descend in the normal position. In catheterization of what would appear to be a slightly displaced but otherwise normal ureter orifice, the chances of entering the aberrant ureter at one time and the normal ureter at another are equal, and the result might lead to the hasty removal of a small but otherwise normal kidney.

HISTOLOGICAL DESCRIPTION

The specimens are remarkably good considering that they are from dissecting room material.

(A) *Right Kidney*. Stain, Hemotoxylin and Eosin. Section shows an apparently normal, healthy kidney which has undergone some slight postmortem degeneration.

(B) *Left Kidney*. Stain, Hemotoxylin and Eosin. In spite of its small size, shows every sign of being otherwise normal.

(C) *Mass X*. Stain, Hemotoxylin and Eosin. Consists of a fibrous tissue which shows varying degrees of density. In the more compact areas the resemblance to ovarian stroma is somewhat striking. The nuclei in this fibrous background are of two types; in the less compact areas they are mostly of the slender,

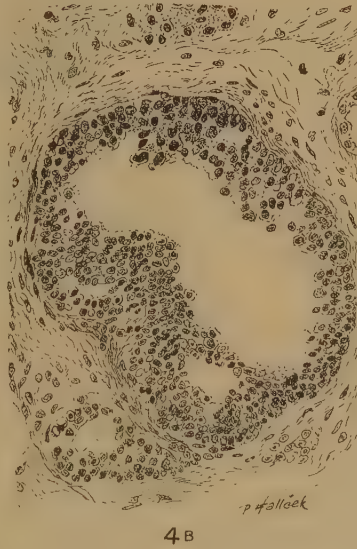
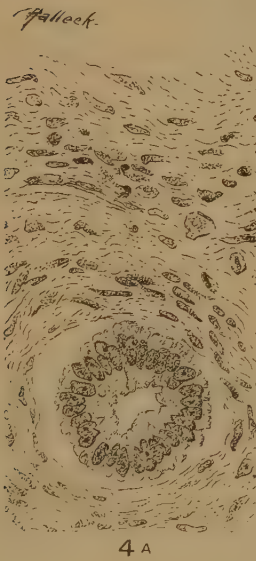
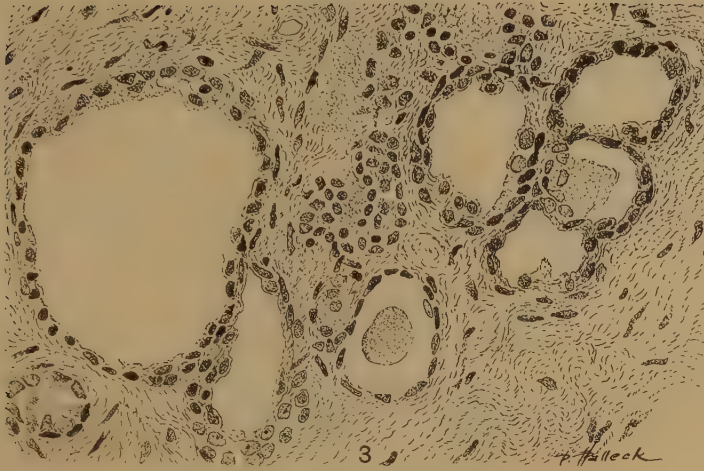
cylindrical type, while in the denser portions there are also many which are round, and may indicate a lymphocytic infiltration.

Embedded in this fibrous background are found at least three different types of tubules. The tubules of Type I are by far the most numerous. They are thin walled and lined with a single layer of epithelium, the individual cells of which are low and not distinct but the nuclei stand out sharply, and are either of a short cylindrical or spherical shape. The size of these tubules varies greatly as seen in fig. 3, but the general appearance is the same. The second type of tubules are those which probably represent the calyces. As seen in fig. 4 (A and B) they are two of distinct sizes, the smaller ones being the more numerous. They are lined with a stratified epithelium which is practically identical with the epithelium lining the aberrant ureter. In figure 4 the similarity is less striking than in the actual specimen. The tubules of type three are very rare. They are distinctly cup shaped in section (fig. 5). The nuclei of the cells lining the concavity are large, round and light staining, and each contains at least one small dark nucleolus. Around the periphery, on account of looking through several layers of cells, it is a little hard to determine just what type of cell constitutes the true lining, but upon close examination of some of the better examples, one would be justified in the belief that they were nothing more than Type I tubules, the lumen of which had simply become plugged with a large type of wandering cell, thus giving them a false cup shape.

In section of the mass through its lateral extremity, where it becomes continuous with the cortex of the left kidney, some perfectly normal kidney tissue is found, the glomeruli of which are intact, the efferent tubules of this portion drain off toward the left kidney.

One more important factor to be emphasized is the absence of glomeruli or their degenerated remains in the main body of the mass. The significance of this fact will be brought up later.

(D) *Ureter from Left Kidney.* Stain, Hemotoxylin and Eosin. As would be expected this is perfectly normal. The epithelium is greatly loosened and torn, but otherwise showed no peculiarities.



Figures 3, 4A, and 4B

(E) *Aberrent Ureter*. Hemotoxylin and Eosin. Mucosa found to be practically identical with that in the normal left ureter. There is considerable increase in the amount of submucous connective tissue the muscle being reduced accordingly, but considering it as a congenital, non-functional ureter the state of preservation of the muscle coat is striking. This is not so unusual however, as we have a like condition of practically non-functional smooth muscle normally present in the ovarian tube and ductus deferens.

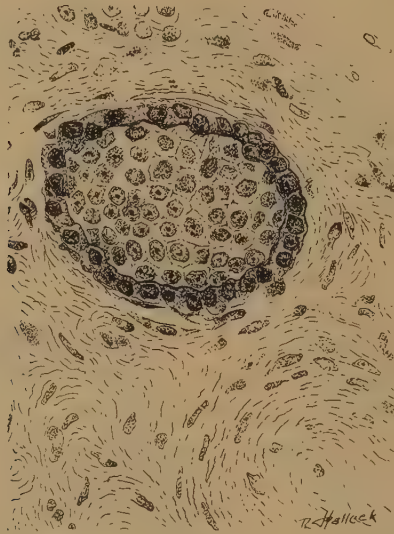


Figure 5

(F) *Sac-Like Structure on Posterior Part of Mass X*. Hemotoxylin and Eosin, also Van Giesons. Sections were made of this in an attempt to discover if there was any type of epithelial lining on its inner surface, but no trace could be found. With hemotoxylin and eosin it seems to be composed of a very loose type of connective tissue, and scattered about through this are what appear to be bundles of smooth muscle. In order to determine this definitely, the Van Gieson's stain was used, and this showed that while the larger part is loose connective tissue, there is considerable smooth muscle present.

(G) *Embryological Considerations.* The possibility of obtaining enough cases of double ureters in embryos, so that a complete picture of the processes taking place which lead to the establishment of the adult position of the vesical orifices, is of course, almost impossible, and at the present time the few specimens available for study simply give a vague hint as to what these steps may be. Certain relations, however, seem fairly constant, and by bringing together these known facts with the later developmental processes of the cloacal structures, certain explanations may be offered.

The rule for double ureters, as stated by Pohlman, is surprisingly accurate and the exceptions to it are apparently relatively few, but only after satisfactory explanation for these exceptions have been worked out, will the whole process be rendered intelligible.

Briefly his rules are:

In incomplete double ureters the ureter from the upper pelvis lies ventral to the one from the lower pelvis and there is a common orifice into the bladder. In complete double ureters the proximal relations are the same, but as they approach the bladder the ureter from the lower pelvis swings lateral to the one from the upper pelvis, and empties into the bladder lateral and slightly above it.

In the case under consideration it is evident that we have a case of incomplete double ureter which tends to act like a complete one, inasmuch as the ureter from the lower pelvis (kidney proper) crosses the one from the upper pelvis (mass on top of the kidney) on the lateral side and comes to lie above it as they enter the bladder, but there is a common orifice. Apparently then the forces which ordinarily act upon the orifices of double ureters and swing the one from the lower pelvis to a higher and more lateral orifice into the bladder, have also produced their effect on the single orifice of these ureters.

In a case reported by Kerr he describes the orifice of the ureter from the upper pelvis as lying medial and superior to the one from the lower pelvis, therefore in direct contradiction to the rule. Similar cases have been reported by Weigert and Hyrtl.

The ureter develops as an outsprout from the dorsal surface of the Wolffian duct near its opening into the urogenital sinus and then divides into an upper and lower pole, which some investigators believe represent the upper and lower divisions of the adult pelvis. Either before, or as this case seems to illustrate, after this division it becomes capped by the primitive nephrogenic tissue and then continues its migration cranially. At an early period the ureter swings from a dorsal to a lateral orifice on the Wolffian duct, and some time later in the pig, but probably immediately following or coincident with this in man, the lower funnel shaped portion of the Wolffian duct unfolds and is taken up into the wall of the growing bladder, thus giving the ureter a separate orifice which is at first on the same level as that of the Wolffian duct. This latter condition is apparently well represented in Embryo Mall 175 (13 mm.), which has a complete double ureter on the left side, the orifices, however, have been slightly displaced in cutting, but from relations in sections just above and below it is likely that the ureters have just gained a separate orifice. I also wish to call attention to the fact that in this specimen there is still a very pronounced curve in the Wolffian duct, it passes downward, makes its bend and then passes upwards through four sections before entering the urogenital sinus. A still more pronounced curve is seen in the ureters. The significance of these facts I will bring up later.

The manner in which the orifice of the ureter becomes permanently located above and lateral to the orifice of the Wolffian duct seems to be the subject of slight differences in opinion. The common explanation, given in text-books of embryology, is that the separation is due to a rapid growth of the bladder wall between the orifices of the ureter and Wolffian duct which results in an upward displacement of the ureter orifice, but there is probably more evidence for the view that the posterior wall of the urogenital sinus is placed downward, carrying with it the orifice of the Wolffian duct. The best evidence for this view is in the case of the female, where the primitive hymen is located at Mueller's tubercle, on the same level and between the orifices of the Wolffian ducts, while in the adult female the hymen has been dis-

placed far below this point to give a new vaginal orifice; the degenerated Wolffian ducts, when they persist as the ducts of Gartner, are found opening beside the hymen, having been carried with it in its displacement. Many abnormalities in the termination of the ureter tend also to show this downward displacement. Thus the cases cited by Morris in which the ureter ends in the urethra, vagina or seminal vesicles are certainly strong proof for such downward displacement. Therefore the most logical view is to consider that the ureter remains more or less stationary, while the Wolffian duct is carried downward, in the male only as far as the pelvic portion of the urogenital sinus, while in the female additional displacement takes place.

Considering that there is a marked downward displacement of the posterior wall of the urogenital sinus while the anterior wall is practically stationary, there must be a line between the anterior and posterior wall which is least affected by this movement, this I shall call the line of 'minimum motion.' Posterior to this line there will be a downward movement, while anteriorly, the wall is practically at rest or undergoing a slight upward migration. therefore any structure which would lie exactly on this line might be simply rotated.

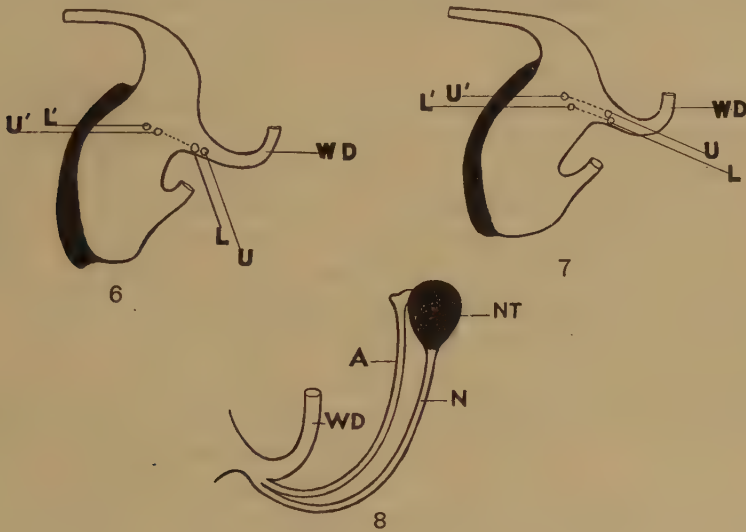
Considering the embryology of the case I am reporting, we may say that the division of the ureter fundament into upper and lower portions was complete enough to effect practically the whole ureter, and as it grew upward it continued as two parts, but the division was not sufficient to give each ureter a separate opening. As development proceeded the single orifice of these ureters migrated from a dorsal to a lateral opening into the Wolffian duct, and when the lower part of the latter unfolded into the urogenital sinus, the common orifice was carried on to the wall of the bladder, thus gaining a separate opening. Had the latter process been entirely normal the common ureter orifice would have been carried to a point anterior to the above mentioned line of 'minimum motion,' and when the downward displacement of the posterior wall began it would not have been affected by it. If, however, we consider a slight inhibition in the unfolding of the cloacal segment of the Wolffian duct, then instead of being car-

ried anterior to the future line of 'minimum motion,' the common orifice was probably carried exactly to this point. Therefore, when the downward displacement began the orifice was simply rotated so as to bring the lower ureter on top of the upper. That there was at the same time some displacement of the common ureter orifice is shown by its relation to the internal urethral orifice fig. 2. This explanation also accounts for the fact that the ureters are crossed just before they enter the bladder. No doubt a similar twist may often occur at the orifice of a single ureter, but would go unnoticed because there would be no way to check it.

As has been shown by Pohlman in the case of double ureters, the lower or dorsal ureter acquires an opening into the Wolffian duct ventral to the upper ureter at the time when they migrate from the dorsal to the lateral side of that structure. I have also called attention to the fact that at the time when the ureters obtain an opening into the urogenital sinus, separate from the Wolffian duct, the latter still makes quite a large bend and then passes rapidly upwards to its opening into the urogenital sinus. Under these conditions it is most natural that the ureter from the lower pelvis (fig. 6 L), which opens into the Wolffian duct ventral to the ureter from the upper pelvis (fig. 6 U) should maintain the higher orifice in the bladder (fig. 6 L'), while the ureter from the upper pelvis, being in close proximity to the line of "minimum motion," is displaced slightly downward. That this downward displacement of the upper ureter is usually very limited is shown by the fact that they ordinarily open very close together. In Dr. Ramsay's case he gives the distance between the orifices as 1.5 cm. In other cases there is an apparent inhibition in the unfolding of the cloacal portion of the Wolffian duct, and the lower ureter having the advantage, due to its more ventral position on the Wolffian duct, is carried beyond the line of 'minimum motion,' while the upper ureter being more dorsal on the duct, is not carried so far, and remains posterior to the line, and is consequently influenced by the downward displacement of the posterior wall of the sinus. Supporting this view we have those rare cases in the adult in which one ureter opens normally into the

bladder, and the other, for example, into the vagina. In the literature at my disposal it was not stated which ureter had been displaced from the bladder, but it was probably the one from the upper pole which was dorsal on the Wolffian duct as rotation occurred.

If at the time when the ureters swing from their dorsal to a lateral position on the Wolffian duct, the lower ureter (Fig. 7 L) should fail to take up a position ventral to the upper ureter (fig. 7 U) then after the unfolding of the Wolffian duct the relations



Figures 6, 7, and 8

would be as in fig. 7 (L' and U'). Therefore if both ureters were moved beyond the line of 'minimum motion,' it would be the ureter from the upper pole that would have the highest orifice into the bladder, but the openings would be close together. This would then account for those cases which are given as exceptions to Pohlman's rule, for example, the case reported by Kerr, the causative factor being the failure of the lower ureter to take up its ventral position, when they migrate on the Wolffian duct. Now if we consider again the possibility of incomplete unfolding of the Wolffian duct, so that one ureter is anterior and one left

posterior to the line of 'minimum motion,' the ureter to be displaced downward, when the orifices are far apart, would be the one from the lower pelvis.

In connection with the Wolffian duct and its course, I wish to call attention to the explanation given by W. Felix in Keibel and Mall for the change in shape of the ventral segment of the cloaca, after the rectal portion has been separated from it. He says: "The dorso-ventral diameter of the abdominal cavity increases with the curvature of the tail and thereby the primary excretory duct becomes at first elongated. As the enlargement of the abdominal cavity increases still more, the primary excretory duct and the ureter, which are fastened to the posterior abdominal wall, draw out dorsally the posterior wall of the ventral remains of the cloaca. The form and position of the ventral remains of the cloaca become altered by these modifications, the cavity becoming almost quadrangular in median section. . . . The cranial wall now becomes curved downward and the lumen, originally quadrangular in median section, becomes divided into three portions." These three portions being the vesico-urethral, the pelvic and the phallic portion of the urogenital sinus. If this explanation is correct then we would expect the curve in the Wolffian duct and ureter to have been straightened during the process of drawing out dorsally the posterior wall of the cloaca. However this is not the case, for in Embryo Mall 175, the ventral remains of the cloaca has already been divided into its three portions, and the bend in the Wolffian duct and ureter is still present and very pronounced and shows no sign of having been influenced by this process.

The developmental possibilities of the mass, in which the aberrant ureter terminates, present many interesting features. Upon simple examination of the gross structure, the tendency would be to classify it as a fused, degenerated, supernumerary kidney, but as pointed out in the histological description, the mass contains no signs of glomeruli or their degenerated remains. This brings up the point as to whether the aberrant ureter was really ever capped by the nephrogenic tissue. From the evidence at hand one would be strongly inclined to believe that it was never com-

pletely covered, but was only partially involved in the nephrogenic tissue (fig. 8 NT), which capped the normal ureter (fig. 8 N). The evidence for this view is rather striking, since the lateral extremity of the mass becomes continuous with the cortex of the kidney proper, and only in this lateral portion of the mass could any glomeruli be found. The glomeruli and tubules found in this portion are perfectly normal, and the efferent tubules lead toward the kidney proper. It would seem reasonable to believe that the fibrous background, in which the atypical tubules are placed, is simply a proliferation of the connective tissue which normally surrounds the growing ureter bud. The tubules, therefore, should be considered as collecting tubules derived from the ureter.

Morris cites a case reported by Ebstein, where in place of the right kidney was found "a pale reddish mass of connective tissue, surrounded by considerable Adipose tissue," this mass was located at the upper end of the right ureter. "The mass was smaller than the normal suprarenal gland; no glomeruli and no uriniferous tubules could be discovered in it." Yet a very narrow ureter and renal pelvis, as well as a very small representative of the renal artery connected with this mass. Morris brings up the question as to whether this should be considered as a specimen of absence of the kidney or a case of rudimentary development, which he designates as "congenital atrophy." Ebstein, he says, regards it as the latter.

If the interpretation of my case is correct, then some rather interesting assumptions can be drawn from it. First, that the primary division of the ureter analage into caudal and cranial poles may take place without being capped by the nephrogenic tissue, and therefore this division is not due to the attraction of the parenchyma. This view is further substantiated by a specimen in our collection (Pig No. 3) in which there is a double ureter on the right side; at its upper limit the one ureter ends blindly and has no connection whatever with the kidney; the second ureter is normal.

Second, that the outgrowth of the collecting tubule system is not entirely dependent on an influence exerted by the nephro-

genic tissue, since in the mass we have many large tubules which probably represent the calyces, and the smaller ones, the collecting tubules.

Third, the abundant blood supply of the mass seems to indicate that it is not the influence exerted by any particular stage of development of the kidney substance, which attracts the vessels.

In closing I wish to acknowledge my indebtedness to certain members of the Department of Anatomy of St. Louis University. I wish to thank Dr. A. G. Pohlman for his many valuable suggestions and hints, and also for his unfailing willingness to give me the benefit of his vast experience and knowledge in matters pertaining to this paper. My appreciation is also extended to Dr. A. Kuntz for his encouragement and valuable suggestions, to M. W. Schmidt and Mrs. B. Nichols for their help in matters pertaining to histological technique, and lastly to Dr. G. L. Streeter of the Carnegie Laboratory of Johns Hopkins Medical School for his kindness in permitting me to use Embryo Mall 175, from which a reconstruction was made.

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Resumen por el autor, James A. Gough,
Universidad de Wisconsin.

Un método de inyección de los vasos sanguíneos para los estudios
roentgenológicos con embalsamamiento simultáneo
del cuerpo.

Si se inyectan los vasos sanguíneos con una masa opaca para los rayos Roentgen y se obtienen placas estereoscópicas de la parte inyectada se pueden conseguir hermosas figuras de los principales vasos sanguíneos y su relación con otras estructuras. En el presente trabajo el autor hace una revisión de algunas de las principales masas de inyección que se han empleado con el expresado propósito, y recomienda el uso de una solución de sulfato bárico en ácido carbólico (fénico), alcohol y glicerina que, simultáneamente embalsama el cuerpo y opacifica los vasos sanguíneos en estructuras opacas a los rayos Roentgen.

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A METHOD OF INJECTING THE BLOOD-VESSELS FOR ROENTGENOLOGICAL STUDIES AND SIMUL- TANEOUSLY EMBALMING

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By injecting the blood-vessels with a mass opaque to the Roentgen rays and taking stereoscopic Roentgenograms, it is possible to get pictures of the arteries and veins of a part as complete as those obtained by injection and corrosion methods and at the same time to preserve the relations of the blood-vessels to other structures. The following paper describes an attempt to devise an injection mass to embalm the body for dissecting-room purposes and at the same time furnish a medium suitable for Roentgenograms. Such a fluid enables one to study the blood supply of a part before or during the course of a dissection without disturbing the tissues for other purposes. Before describing the method which we have adopted, I shall give a brief résumé of some of the chief methods which have been employed for rendering the blood-vessels opaque to the Roentgen rays.

a. Calcium sulphate in water

This method accredited by Dr. Hildebrand, of Marburg, Germany, to an Italian, U. Dutto, is the earliest mentioned in the literature, having been used as early as 1896. I have been able to obtain no details concerning the use of this method.¹

¹ The earliest reference I have found in English literature to Roentgenology of the blood-vessels is that of Sidney Rowland, editor of the "Archives of the Roentgen Ray," who in reporting a meeting of the Roentgen Society in St. Martin's Town Hall, London, November 5, 1897. wrote, "Dr. Hedley, . . . a stereoscope showing amongst other objects an injected human brain." The method of injection was not described.

b. Metallic mercury

The earliest work reported with this substance is that of Mr. F. H. Glew, England, who in August, 1899, presented a radiogram of the arterial system of an injected infant well-developed and still-born at full term:

The infant was injected by Mr. C. Ind-Musgrove, a scholar at St. Thomas's Hospital, with four pounds of mercury, into the external circumflex branch of the femoral artery. This was done with a hypodermic needle inserted into the artery, and connected by rubber tubing to a funnel containing mercury, which was allowed to run in by its own weight, the pressure being about 5 inches of mercury.

Leopold and Leisewitz, Germany, in preparing their "Roentgen-atlas," published in 1909, used mercury in x-raying the vessels of the placenta.

Some of the most beautiful results obtained by any of the workers in this field were those of A. G. Fryett, F.R.M.S., Melbourne, Australia, who published the following series of pictures: ('03) Radiographs of a shoulder, hand, half a human skull, and a human foetus, and a stereoradiograph of an elbow-joint—arteries injected. ('04) A radiograph of the knee, and one of the leg showing a bullet in situ. Also a radiograph of the thorax, showing a double innominate artery. ('05) Stereoscopic plates of the heart showing injected coronary arteries. ('06) Radiograph of the heart, coronary vein injected, and one of an injected scalp. ('07) Radiograph of the female pelvis—arteries injected. His pictures are very striking and, I think, the most beautiful in the literature, but he gave no report of the method he used. A clue to his method is given in a later reference ('g. Red lead,' Jamin and Merkel).

c. Blue ointment

The earliest work on injected vessels in Germany seems to have been that of Doctor Optiz, a physician in the General Hospital of Hamburg-Eppendorf, who, in September, 1897, reported the results of his experiments in intravascular injections of various substances opaque to the x-ray. He experimented with metallic

mercury, but rejected it because of its weight, for, when injected it ruptured the smaller vessels, especially in the dependent parts and less dense organs, and the resulting extravasations blurred the pictures. He then turned his attention to red lead or cinabar, but after a few experiments discarded this in favor of a warm injection-mass. He writes:

Very practical is the official blue ointment (graue Salbe) which contains $33\frac{1}{3}$ per cent of mercury. In this concentration, it has the property of being very opaque to the Roentgen rays, penetrates well into the finer vessels, and then remains there. . . . The technique suggested to me by the head-physician, Dr. Sick, is as follows: Thoroughly warm the part to be injected, the injection-mass, and the syringe in hot water, and then make the injection into one of the principal vessels.

He evidently did his work on amputated limbs, as there is no mention made of any cadavers used. A fine picture of the arteries of the wrist and hand injected in this manner was shown. Eug. Fraenkel, of the Pathological Institute in this hospital, in studying the blood-supply of the vermiform appendix ('05) used practically the same method. The intestine was warmed in hot water and then injected through the ileocolic artery with warm blue ointment containing sufficient wax to make it harden readily, then cooled and x-rayed. This method was also the suggestion of Dr. C. Sick.

d. Chrome yellow

This substance was used by Doctor Spalteholz, of Leipzig, in 1907 in studying the coronary arteries of the heart, rendered transparent by benzol and carbon bisulphide after hardening in alcohol.

e. Mercury, turpentine and wax

Doctor Hildebrand, of Marburg, Germany, experimented with mercury, blue ointment, and other compounds in making intravascular injections, but found all of these inferior to the mercury-turpentine mixture, of which he claims to be the originator. His method is to take, by weight,

Mercury.....	1000
Terebinth. Com.....	200

Mix thoroughly, and then add:

Yellow wax.....	40
Suet.....	60
Lard.....	50

The entire mass is then heated and mixed to form a homogeneous suspension, and injected with a warm syringe into the arteries of the part, which likewise must be well warmed.

Dr. E. Lexer, University of Berlin, in studying the blood supply of bones, injected them with a mixture of oil of turpentine, wax, and mercury, presumably in the same manner as that given above.

Dr. George Preiser, orthopedic surgeon, Hamburg, in studying the bones of the wrist, injected them according to Dr. Lexer's method.

Dr. Gustav Delkeskamp, Königsberg, in studying the blood supply of bones in various diseases and fractures, also used the turpentine-oil-wax-mercury suspension, but after warming the part injected, washed out the blood remaining in the vessels with warm salt solution before making his injection.

f. Red oxide of mercury

This method of injection was developed by Dr. Addinell Howson, Philadelphia. He presented Roentgenograms of a three-year-old child showing pictures of the arteries and veins on the chest, abdomen, and pelvis, and the anastomoses about the hip, knee, ankle, and foot. The body was preserved by an ordinary injection not containing heavy metal salts, plus a slight amount of formaldehyde. Twenty-four hours later, there was injected into the femoral artery "a watery solution of starch, cold, colored with red oxide of mercury, light English vermilion. This was followed by an injection into the femoral vein (cephalod) of a cold watery solution of starch impregnated with subnitrate of bismuth."

g. Red lead

The editor of "Archives of the Roenten Ray," in reviewing a book, "Stereoscopic skiagrams of the coronary arteries of the human heart under normal and pathological conditions," by Prof. F. Jamin and Dr. H. Merkel, of Erlangen, Germany, writes as follows:

As pointed out in their preface, the idea was suggested to the authors by the very beautiful skiagram of the injected coronary arteries taken by Mr. A. G. Fryett, of Melbourne. . . . The method used by the authors bids fair to be of great utility in the study of anatomy and pathology. Mr. Fryett used, we believe, liquid mercury as his material for injection. Doctors Jamin and Merkel made use of a suspension of red lead in a 10 per cent solution of gelatin, the heart having been previously immersed in an ice-cooled solution of 5 per cent formalin.

Dr. Hauch ('03) developed a more complicated method in his study of normal and pathological kidneys with special reference to their blood supply, and used, by weight,

Red oxide of lead.....	120
Liquid paraffin.....	120
Oleum terebinthinae.....	60

In other older organs, not carefully preserved, he used

	<i>parts</i>
Red oxide of lead.....	80
Liquid paraffin.....	80
Oleum terbinthinae.....	50

Dr. E. Vogt, Kgl. Frauen-Klinik, Dresden, Germany, used the method of Hauch in studying the placental blood supply.

h. Colloidal silver

E. H. Skinner, M.D., of Kansas City, found that a 5 per cent solution of colloidal silver will give a shadow on the Roentgen negative. He used colloidal salts of silver in injecting the vessels in an amputated arm, and obtained good pictures of the 'blood-vessels and capillaries.'

i. Bismuth in oil

Dr. R. Stegmann, Vienna, to illustrate an article on the surgery of the foot, presented a picture in which the arteries were injected with a 25 per cent suspension of bismuth in oil.

j. Barium sulphate in water

F. M. Smith injected the coronary arteries in human and canine hearts with normal salt solution at 37°C. until the salt solution returned practically clear. Following the infusion, the coronary arteries were injected with a mixture of 2 parts barium sulphate and 10 parts water, to which was added a small amount of traga-canth to hold the metallic substance in suspension.

k. Starch and pigment

W. S. Miller ('18) has described the use of a starch mass mixed with pigment for differential Roentgenograms of the arteries and veins of the lungs. The mass is made by mixing cornstarch and the pigment with 70 per cent ethyl alcohol. No definite directions are given as to proportional quantities, since Miller found that the materials vary in quality and hence there is a variation in quantity to be determined experimentally. When the larger vessels only are to be photographed, the mass is made thicker and the pressure less (100 mm. of Hg.) than when the smaller vessels are to be made visible. For the arteries vermilion granules are used for pigment, for the views ultramarine blue. The former give a smooth, the latter a granular shadow on the x-ray plate. Before the Roentgenogram is taken, the lungs are distended.

After briefly reviewing these methods and the results shown, it was evident that there was slight possibility of our improving on them in so far as photographic excellence alone was concerned, but it seemed probable that we might develop a method which would apply in a more practical manner to the needs of the usual anatomical laboratory. In order to study scientifically any system in the human body, and especially the vascular system, the findings in many bodies must be summarized. One cannot make

an authoritative statement on the normal arrangement of blood-vessels from the study of a single specimen. Again, anomalies found in the dissecting-room can be recorded in no better manner than by the x-ray plate. Furthermore, any method of injection ought to be simple, so that the average laboratory technician can apply it, and ought to provide at the same time for the preservation of the body. The laws of Wisconsin on this subject read as follows: "As soon as received all such bodies will be at once carefully embalmed and will be kept at least two months before being used for the purpose of dissection." These considerations may be summarized by stating that our problem was to develop a simple, inexpensive method of injecting blood-vessels of the human body for x-ray purposes and at the same time embalming it.

It was Dr. C. R. Bardeen's suggestion that we experiment with barium sulphate, the most commonly used substance in x-raying the gastro-intestinal tract, in combination with the preserving fluid used as a routine in this laboratory. This preserving fluid consists of, by volume:

Phenol, C. P.....	20
Glycerin, C. P.....	40
95 per cent ethyl alcohol.....	40

It has been used here with perfect success for years, most of the bodies not being used for dissection inside of one or two years from date of embalming.

Acting upon this suggestion, the first injection was made December 3, 1918, into the right brachial artery of cadaver no. 467 peripherally, the central end of artery being tied. A rather heavy suspension of barium sulphate was injected under 4 pounds' pressure. The rest of the body was preserved in the usual manner. Good pictures of the arteries of the arm and hand were obtained.

December 7, 1918, cadaver no. 468 was injected through the right femoral artery, both centrally and peripherally with a heavy suspension of 3.5 kilos barium sulphate in 8 liters of injection fluid, 6 pounds' pressure for 30 minutes being applied. No further provision was made to cause the barium to adhere to the

vessel walls. Pictures were then taken of the intact body; those of the limbs were good, but the thorax and abdomen seemed to contain so much of the injection mass that they were opaque to the rays. Further preservation was then provided in the manner used here, namely, the body was thickly coated with vaselin and then wrapped with successive layers of paper and gauze, and stored in the vault with the other cadavers, where it remained until March 25, 1919.

On this date, it was unwrapped and carefully examined, and was found to be very well preserved. This finding was further confirmed by dissection. The abdominal and thoracic cavities were opened and the viscera removed. The injection mass in the smaller arteries (below 2 or 3 mm. in diameter) was firmly adherent to them, but when larger vessels were cut, the fluid oozed considerably. Further, in the retroperitoneal fat, an extravasation of the injection mass had occurred, and the same was true back of the parietal pleura in the thoracic cavity, thus accounting for the opacity of these regions in the earlier pictures. In removing the viscera, the vessels were ligated at two points and severed between the ligatures. After removing the thyroid gland, the body was decapitated, and the head was split in the midline. Dr. H. Curl then took stereoscopic Roentgenograms of the following: the two halves of the head, thyroid gland, heart, liver, spleen, right and left kidneys, and the small intestine.

The arteries of the head were well injected, a slight amount of the barium also showing in the superior sagittal and lateral venous sinuses. In regard to the viscera x-rayed, there is little to be said, except that they showed uniformly good injection of the arteries. In order to get a good picture of the heart, it was necessary to wash out of the chambers the injection mass that adhered to them. The stereoscopic effect was greatly improved in the pictures of the intestines by inflating the latter with air under very light pressure. This concluded the x-ray work on cadaver no. 468; the limbs were stored away awaiting demand for dissection, and at this date (June 1, 1919) are as well preserved as similar specimens injected in the same manner minus the barium sulphate.

To apply this method of injection in a really extensive, practical manner, several modifications were necessary, which may be summarized in the three problems which we then endeavored to solve, namely:

1. Is it necessary to use such a heavy suspension of barium sulphate?

2. To enable one to dissect the body later, how prevent the oozing of the varium every time a vessel is cut?

3. The injected vessels were white. How present them in the color the student ordinarily associates with arterial blood?

1. The body of a dog was injected April 15, 1919, using a much thinner suspension of barium, namely, 150 grams to a liter of injection fluid. Somewhat later the body of a craniopagus was treated in the same manner, and the arteries in both cases showed up very well by fluoroscope and roentgenogram.

2. Previously, in embalming the bodies in this laboratory, it has been customary, twenty-four hours after making the original injection of preserving fluid, to inject intra-arterially about a liter of a thin suspension of Prussian blue in shellac, to make the arteries stand out prominently in the dissection. This method was modified and applied to the present case. The day after embalming the dog previously mentioned, about 100 cc. of an alcoholic solution of shellac was injected into its left femoral artery. The arteries were examined daily thereafter, and on the twelfth day it was found that the barium no longer oozed on sectioning them, but was firmly adherent to their walls. This was true not only of the smaller vessels, but of the aorta and common iliacs as well.

3. No experimental work was done in trying to improve on the color of the injected vessels, as it seems almost unnecessary. The barium makes them stand out very prominently, but the addition of cinnabar, red oxide of mercury, or any other insoluble, red, metallic salt to the barium suspension in no manner interferes with the x-ray work, and gives the vessels the necessary redness in case this is desired.

SUMMARY

I should recommend as a routine procedure in the anatomical laboratory the injection of the arteries in the following manner:

1. On the day of arrival of the body, inject the arteries with the phenol-glycerin-alcohol mixture containing barium sulphate in the proportion of 150 to 200 grams of barium sulphate to the liter of fluid, applying 3 or 4 pounds' pressure for about an hour. If desired, the barium may be colored red by the addition of an insoluble red salt.

2. The day following, inject, also intra-arterially, about 1 liter of shellac.

3. Further preservation may be provided by the tank method or by wrapping the body in paper and cloth after coating it with vaselin.

By this method, the arteries of the body may be x-rayed at any time, and the body will keep indefinitely or may be dissected as soon as the law will permit.

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Resumen por los autores, H. W. Norris y Sally P. Hughes,
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El órgano sensorial espiracular de los elasmobranquios, ganoideos
y dipnoos.

En conexión con el espiráculo o hendidura hiomandibular de los elasmobranquios adultos y en estados del desarrollo de los ganoideos y dipnoos se han descrito varios divertículos, algunos de ellos con órganos sensoriales. Estos órganos sensoriales espiraculares están inervados por un ramo ótico facial o por un pequeño nervio que nace en la inmediata vecindad de dicho ramo. La presencia de ampollas de Lorenzini en el espiráculo de algunos embriones de Selacios y la estructura del órgano espiracular de *Squalus acanthias* conducen a la conclusión de que el último es una ampolla de Lorenzini sumamente modificada.

Translation by José F. Nonidez
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THE SPIRACULAR SENSE-ORGAN IN ELASMO- BRANCHS, GANOIDS AND DIPNOANS

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ONE FIGURE

Certain diverticula of the spiracular cleft in Elasmobranchs have been described, to which various interpretations have been given. Johannes Müller ('39) finds in a number of genera of the Plagiostomes a canal opening on the mesial wall of the spiracular cleft and directed transversely toward the lateral wall of the cranium, its blind sac-like end in close proximity to the otic labyrinth. He suggests an accessory auditory function for this diverticulum. Wright ('85 a and b) describes in *Mustelus* not only the "auditory diverticulum" of Müller, but another which has a distinct sense-organ, innervated, as he believes, from the ramus pretrematicus VII. He also finds in *Lepidosteus* and *Amia* in the hyomandibular cleft a diverticulum "with a long free neuromast (Nervenhügel) supplied by a distinct branch of the ramus oticus VII." Van Bemmelen ('86) finds two diverticula on the inner wall of the spiracular cleft of Elasmobranchs, a 'dorsaler Spritzlochanhang,' which corresponds to Müller's auditory diverticulum, and a 'ventraler Spritzlochfollikel,' which is evidently Wright's sensory diverticulum. Van Bemmelen makes no suggestion of a sensory function of these diverticula, but believes them to be remnants of gill-clefts. The dorsal diverticulum he finds in all of the Squalidae, but not in *Raja* and *Torpedo*; the ventral diverticulum in all Selachians, except *Acanthias* and *Heptanchus*. Ridewood ('95) recognizes the dorsal and ventral spiracular diverticula of Müller and van Bemmelen, but apparently sees no suggestion of a sensory character in them. Hoffman ('96) finds in the spiracle of a 28 mm. embryo of *Acanthias* a sense-organ innervated by a nerve which he considers as probably the equivalent of the ramus

oticus VII. Allis ('97) confirms the discovery by Wright of a sense-organ in the spiracular cleft of *Amia*, innervated by the ramus oticus VII. He also ('02) describes the spiracular follicles in *Mustelus*, noting that one of them contains a sense-organ innervated, not as stated by Wright, by the ramus pretrematicus, but by the ramus oticus VII, or more correctly stated, by a branch that arises from the buccal ganglion close to the r. oticus.

Landacre ('17) observes in the 22mm. embryo of *Squalus acanthias* that the ramus oticus after supplying twigs to a lateral line primordium sends a branch into the anterior wall of the spiracle.

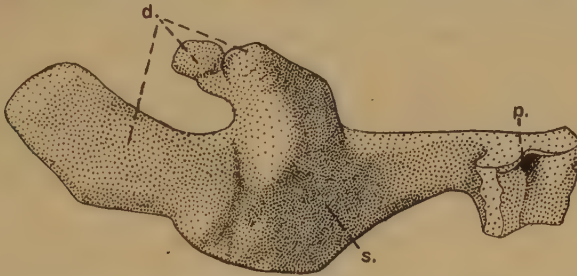
Brohmer ('08) finds in the 45mm. embryo of *Spinax niger* a small group of ampullae of Lorenzini on the anterior wall of the spiracle.

Cole ('95) states that the ramus oticus in *Chimaera* besides innervating the first eight sense-organs of the infraorbital canal supplies also the most ventral of the ampullae of Lorenzini opening on the surface by the large occipital pores.

Pinkus ('95) describes and figures in *Protopterus* a peculiar vesicular sense-organ imbedded in cartilage near the anterior end of the ear capsule, innervated by a small nerve that arises from the main lateral line division of the facialis near the origin of the ramus oticus VII. "Das Organ besteht aus einer kleinen kugeligen Blase als Mittelpunkt an die sich nach vorn, nach hinten und nach innen längliche, dünne Röhren ansetzen, welche alle drei blind enden. . . . Das Organ ist zweifellos ein Derivat des Seitenkanales." Through the kindness of Professor J. S. Kingsley the writers have been able to verify from a study of serial sections the account given by Pinkus. Agar ('06) finds in *Lepidosiren* an organ of similar shape and situation, which he calls "Pinkus' organ," of the nature of whose innervation he is uncertain. He studies the development of this structure in both *Lepidosiren* and *Protopterus* and shows beyond question that in each it is a derivative of the hyomandibular cleft. He states without qualification that it does not belong to the lateral line system, although it is of epiblastic origin.

The writers find opening on the anterior mesial wall of the spiracular cleft in *Squalus acanthias*, both embryo and adult, a

tubular organ, which bears one or more sense-organs. The organ shows great variability in form and structure. In the most fully differentiated condition the small pore in the spiracular wall leads into a sac-like expansion with which are connected three diverticula, two short and cup-like and the third much elongate (see figure). The entire organ with its three diverticula evidently represents a much modified ampulla of Lorenzini. Each of its terminal pouches has a sensory thickening with a special nerve supply. The wall of the elongate pouch is composed mostly of sensory epithelium, among the cells of which are the very elongate sensory cells of the characteristic columnar club-shape. This tubular organ can hardly be considered as rudimentary, although in some instances it is much simpler in character than the fore-



A model of the spiracular organ of *Squalus acanthias* (pup stage), drawn from the left lateral aspect. *d*, The three sensory diverticula. *p*, Pore leading into the cavity of the spiracle. *s*, Sac-like expansion or vestibule. $\times 60$.

going statements imply. The nerve supply of the spiracular organ in *Squalus* comprises fully one half of the ramus oticus VII.

In general the writers agree with Allis in his account of the spiracular organ in *Mustelus*. A statement of the innervation of the organ in *Mustelus* is somewhat a matter of definition. If by the term, ramus oticus, we mean, as in *Squalus*, a branch of the lateralis VII arising from a special ganglionic prolongation of the buccal ganglion, and innervating the horizontal section of the infraorbital canal, then the r. oticus of *Mustelus* does not innervate the spiracular sense-organ. For in *Mustelus* the latter is innervated by a small nerve which arises from the buccal ganglion, but which also innervates, not the horizontal section but the postorbital section of the infraorbital canal.

Van Bemmelen reports the absence of the ventral 'Spritzloch-follikel' in *Acanthias*. But because of the more dorsal situation of its external pore he evidently confuses it with a dorsal 'Spritzlochanhang.' In *Squalus acanthias* it is large enough in the adult condition to be dissected out easily by a skillful operator.

In *Raja radiata* the writers find a ramus oticus VII innervating a diverticular sense-organ, the follicle, however, not opening into the spiracle, but on the roof of the pharynx at the anterior border of the inner pharyngeal opening of the hyomandibular cleft.

There can be little doubt that the spiracular sense-organ of Elasmobranchs and Ganoids and Pinkus' organ of the Dipnoans are homologous structures, derivatives of the lateral line system of sense-organs. The presence of ampullae of Lorenzini in the spiracle of the embryo, as shown by Brohmer in *Spinax*, the form and structure of the diverticulum and vesicle as seen in *Squalus* and in *Protopterus* and *Lepidosiren*, the innervation of ampullae of Lorenzini by the ramus oticus in *Chimaera* (if Cole's account is correct), are indicative that we are dealing here, not with canal-organs or naked neuromasts, but with much modified ampullae of Lorenzini.

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PROCEEDINGS OF THE AMERICAN ASSOCIATION OF ANATOMISTS

THIRTY-SIXTH SESSION

United States National Museum, Washington, D. C.
April 1, 2, and 3, 1920

THURSDAY, APRIL 1, 9.30 A. M.

The thirty-sixth session of the American Association of Anatomists was called to order by President Robert R. Bensley, who appointed the following Committees:

Committee on Nominations for 1920: Professor H. H. Donaldson, Chairman; and Professors J. L. Bremer and R. E. Scammon.

Auditing Committee: Prof. A. T. Kerr, Chairman; and Prof. L. H. Weed.

The remaining morning session was devoted to the presentation of scientific papers.

FRIDAY, 11.30 A.M. ASSOCIATION BUSINESS MEETING, PRESIDENT ROBERT R. BENSLEY, PRESIDING.

The Secretary reported that the minutes of the Thirty-Fifth Session were printed in full in *The Anatomical Record*, volume 16, number 3, pages 129 to 135. On motion, seconded and carried, the minutes of the Thirty-Fifth Session were approved by the Association as printed in *The Anatomical Record*.

Professor A. T. Kerr reported for the Auditing Committee as follows: The undersigned Auditing Committee has examined the accounts of Doctor Charles R. Stockard, Secretary-Treasurer of the Association of Anatomists, and finds the same to be correct with proper vouchers for expenditures and bank balance on January 20th, 1920, of \$173.12.

(Signed) A. T. KERR,
L. H. WEED.

The Treasurer made the following report for the year 1919:

Balance on hand January 8, 1919, when accounts were last audited.....	\$211.59
Receipts from dues 1919.....	2,693.74
Total deposits	\$2,905.33
Expenditures for 1919:	
Expenses Secretary-Treasurer. Pittsburg Meeting.....	\$51.58
Postage and telegrams.....	53.60
Printing and stationery.....	61.00
Collection and exchange on drafts	5.03
Stenography, typewriting.....	46.50
Return of excess payment by check.....	1.00
Wistar Institute, subscriptions to Journal of Anatomy, Anatomical Record, etc.....	2,513.50
Total expenditures.....	2,732.21
Balance on hand.....	\$173.12
Balance on hand deposited in the name of the American Association of Anatomists in the Corn Exchange Bank, New York City.	

On motion the report of the Auditing Committee and the Treasurer were accepted and adopted.

The Committee on Nominations through its Chairman, Professor J. Playfair McMurrich, placed before the Association the following names: For President, Professor Charles F. W. McClure; for Vice President, Professor T. Wingate Todd; for members of the Executive Committee, term expiring 1923, Professors G. Carl Huber and Lewis H. Weed.

On motion the Secretary was instructed to cast a ballot for the election of the above named.

The Secretary presented the following names recommended by the Executive Committee for election to membership in the American Association of Anatomists:

- ADELMANN, HOWARD B., B.A., Assistant in Histology and Embryology, *Cornell University, Ithaca, N. Y.*
 ARAI, HAYATO, M.D., Chief Gynecologist, *Sapporo Hospital, Sapporo, Japan.*
 ATTERBURY, RUTH RAND, A.M., Assistant in Histology, College of Physicians and Surgeons, *Columbia University, 437 West 59th St., New York City.*
 BARTSCH, PAUL, Ph.D., Professor of Zoölogy, *George Washington University, Curator Marine Invertebrates, U. S. National Museum, Washington, D. C.*
 CHAGAS, CARLOS P., M.D., Professor of Histology and Pathology, *Bello Horizonte Medical School, Minas-Geraes, Brazil, South America.*

- CHARLTON, HARRY HAYWARD, A.B., A.M., Graduate Assistant in Biology, *Osborn Zoological Laboratory, Yale University, New Haven, Conn.*
- DODDS, GIDEON S., Ph.D., Assistant Professor of Anatomy, *West Virginia University Medical School, Morgantown, W. Va.*
- ERDMANN, C. A., M.D., Associate Professor of Anatomy, *Institute of Anatomy, University of Minnesota, Minneapolis, Minn.*
- FAWCETT, EDWARD, M.D., Professor of Anatomy, *University of Bristol, England.*
- FIRKET, JEAN, M.D., Instructor in Anatomy, *Johns Hopkins Medical School, Baltimore, Md.*
- FRAZER, JOHN ERNEST, M.D., F.R.C.S., Professor of Anatomy, *University of London, St. Mary's Hospital Medical School, London, W. England.*
- GRANT, V. C. BOILEAU, M.B., Ch.B., F.R.C.S., Professor of Anatomy, *University of Manitoba Medical College, Winnipeg, Canada.*
- HOFFMAN, CLARENCE, M.D., Demonstrator in Anatomy, *Jefferson Medical College, 1621 Pine St., Philadelphia, Pa.*
- HUNTER, OSCAR B., M.D., Professor of Anatomy, *George Washington Medical School, 1335 H St. N. W., Washington, D. C.*
- INGVAR, SVEN, M.D., Docent in Neurology, *University of Lund, Lund, Sweden.*
(Present address: *Osborn Zoological Laboratory, Yale University, New Haven, Conn.*)
- JOHNSTON, THOMAS BAILLIE, M.B., Ch.B., Professor of Anatomy, *University of London, Guy's Hospital Medical School, London, S. E. 1., England.*
- KUDO, TOKUYASU, M.D., Professor of Anatomy, *Nagata Medical College, Japan.*
(Present address: *Institute of Anatomy, University of Minnesota.*)
- LATTA, JOHN S., A.B., Instructor in Histology and Embryology, *Cornell University, Ithaca, N. Y.*
- LIPSHUTZ, BENJAMIN, M.D., Instructor in Neuro-anatomy, *Jefferson Medical College, 1007 Spruce St., Philadelphia, Pa.*
- MAVOR, JAMES WATT, M.A., Ph.D., Assistant Professor of Zoology, *Union College, Schenectady, N. Y.*
- OWEN, WILLIAM O., M.D., Colonel U. S. A. M. C. (Retired), *2719 Ontario Road, Washington, D. C.*
- OKAJIMA, K., M.D., Professor of Anatomy, *Keio University Medical College, Tokio, Japan.*
- PING, CHI, Ph.D., Fellow in Anatomy, *Wistar Institute of Anatomy, Woodland Ave. and 36th St., Philadelphia, Pa.*
- RUPERT, R. R., M.D., Professor of Gross Anatomy, *University of Utah, School of Medicine, Salt Lake City, Utah.*
- SANSOM, GEORGE SAMUEL, B.Sc., M.C., D.F.C., Honorary Research Assistant, *Department of Zoology, University College, Gower St., London, W. C. 1, England.*
- SHEPPARD, HUBERT, M.A., Ph.D., Assistant Professor of Anatomy, *University of Kansas, School of Medicine, Lawrence, Kansas.*
- SPAULDING, M. H., A.M., Assistant Professor of Zoology, *University of Montana, Bozeman, Montana.*
- SPEIDEL, C. C., Ph.D., Professor of Zoology, *St. Lawrence University, Canton, N. Y.*

VAN DER STRICHT, OMER, M.D., Professor of Histology and Embryology, *University of Ghent, 71 Marché au lin, Ghent, Belgium.*

WATSON, ERNEST M., A.M., M.D., Instructor in Applied Anatomy, University of Buffalo, *494 Franklin St., Buffalo, N. Y.*

WHITNALL, S. E., M.A., M.D., B.Ch., Professor of Anatomy, *McGill University, Montreal, Canada.*

WILHELMJ, CHARLES S., A.B., Teaching Fellow in Anatomy, St. Louis University Medical School, *1402 South Grand Ave., St. Louis, Mo.*

On motion the Secretary was instructed to cast a ballot for all the candidates proposed by the Executive Committee. Carried.

The Secretary then announced the following names as dropped from the list of members on account of non-payment of dues for the past two years:

DR. M. M. MILLER, *North Western University.*

DR. E. H. NORRIS, *University of Minnesota.*

DR. S. S. SCHOCHET, *Chicago, Ill.*

DR. R. J. TAINTOR, *St. Louis University.*

DR. E. I. WERBER, *Prater Vivarium, Vienna.*

It was announced that the Executive Committee had voted to hold the next annual meeting during the week before Easter Sunday, 1921, the place to be decided later.

The Secretary then read the following letter from Professor Arthur Keith:

DEAR DR. STOCKARD,

As President of the Anatomical Society of Great Britain and Ireland, may I send to the American Association of Anatomists the warmest greetings of their British colleagues?

I would take this opportunity of expressing our unbounded admiration for the work your Association is doing, and the enterprise it is showing, in developing anatomical knowledge. On this side we hope that we may have opportunities of meeting from time to time and of comparing methods and of exchanging ideas. May I also say how gladly we shall welcome American Anatomists who care to become members of our Society.

Believe me, Dear Dr. Stockard,

Yours Sincerely

ARTHUR KEITH.

The following committees appointed since the last meeting were announced:

Nomenclature Committee: R. R. Bensley, Chairman; F. T. Lewis, H. H. Donaldson, H. S. Murphey, J. S. Kingsley.

Committee for Co-operation with National Research Council:

C. M. Jackson, Chairman; C. R. Stockard, W. H. Lewis.

Committee on International Congress: G. S. Huntington, Chairman; C. J. Herrick, L. H. Weed.

The Committee on Nomenclature reported as follows:

Your Committee finds that the British Committee appointed to revise the Anatomical nomenclature has made considerable progress with its revision. The revision so far is reported to have developed along lines consistent with the principles followed in the B.N.A. The Committee considers the time inopportune for a general international revision and proposes that it be continued for one year to receive and report on the final revision made by the British Committee.

Signed for the Committee,

R. R. BENSLEY,
Chairman.

The report was accepted as presented and the Committee continued.

The Committee on International Congress made an informal report through its Chairman, Professor Huntington, and introduced the following resolution:

RESOLVED: That it is the sense of the American Association of Anatomists that it views with sympathy and interest the efforts at present in progress in the European Countries as well as in the United States looking toward the resumption of international scientific relations as soon as social and economic conditions render this possible.

This resolution was passed by the Association and the Committee continued.

It was moved by Professor Stockard and seconded by Professor Bardeen that the clause in Article II, Section 1, of the Constitution which now reads—"The President and the Vice-President shall be elected for two years, the Secretary for four years" be changed to read: The President and the Vice-President shall be elected for one year, the Secretary for two years.

This motion is to be printed and mailed to members at least one month in advance of the next annual meeting and voted on at that meeting.

The Committee on the Publication of Anatomical Journals reported through its Chairman, Professor Streeter, that the

findings of the Committee had been printed and distributed to all members. The printed findings consisted of two parts, first, a majority report recommending that the Association adopt "Plan A" and accept the title of the Journals and arrange for their publication signed by Professors G. L. Streeter, Chairman, and C. R. Bardeen; second, a minority report recommending that the Association adopt "Plan B" and place the title and publication of the Journals in the hands of The Wistar Institute: Signed by Professor C. M. Jackson.

It was moved by Professor Bardeen and seconded by Professor Begg, that the Association accept the majority report, and take over title of the Journals and responsibility for their publication.

Professor Huber, a trustee of the Journals, stated that the three trustees took the position that they were merely seeking the advice of the Association, and did not consider themselves bound to follow the action taken. They were responsible, and the Association's action simply advisory. He then moved that the Association not accept the motion by Professor Bardeen, but a substitute motion to adopt "Plan B" for the transfer of the Journals to The Wistar Institute. Professor Jackson was second for the substitute motion.

The Secretary then stated that most members had misunderstood the proposition made by the Journal trustees and had felt that the matter was presented to the Association for decisive action and not simply for advice. As a result of this attitude the Committee appointed by the Association had taken the matter very seriously and spent much time and energy as is shown by their printed report. The officers of the Association had also considered the matter of sufficient importance to expend considerably more than one-third of the Association's annual income on the publication of the Committee's report, thus rendering the present year's dues insufficient for current expenses.

The motion was further discussed by Professors Emmel, Meyer, Evans, Huntington, Greenman, Knowler and Bardeen.

The question was then called for, and voted by a majority of 45 against 26 to allow the substitute motion.

The motion was then to adopt "Plan B" for the transfer of the Journals to The Wistar Institute. This motion was carried by a standing vote of 45 against 26.

On motion the business session adjourned.

SATURDAY, APRIL 3. A BUSINESS SESSION FOLLOWED THE MORNING SCIENTIFIC SESSION.

A committee on resolution reported as follows:

Through the untimely death of Dr. Elmer Ray Hoskins, The American Association of Anatomists has lost one of the most talented and promising of its younger members. His marked ability, energy and enthusiasm gave assurance of a brilliant career in the field in which he had already accomplished much. To Mrs. Margaret Morris Hoskins, who has shared so actively and efficiently in her husband's work, the Association desires to extend its heartfelt sympathy.

(Signed) C. M. JACKSON, *Chairman*,
E. R. CLARK
H. D. SENIOR

It was moved by Professor Huber and carried that the report be accepted as read, printed in the minutes and that a copy be sent to Mrs. Hoskins by the Secretary.

A Committee appointed by the President introduced the following resolution:

The American Association of Anatomists desires to express its gratification at the appointment of one of its members, Sir Auckland Campbell Geddes, as British Ambassador to the United States, and trusts that while he is engaged in cementing the political friendship between two great nations he will at the same time be able to continue those scientific friendships already cemented in our Association.

(Signed) CHARLES R. BARDEEN,
HERBERT M. EVANS.

The report of the Committee was accepted as read.

It was moved and carried that the members of the Association of Anatomists since its organization has been using the metric system and therefore feel that the adoption of this system by the United States Congress would be advantageous in unifying methods of expression.

It was moved by Professor Jackson and seconded by Professor Terry: That the Executive Committee be authorized to appoint

a Committee to cooperate in arrangements for the publication of Journals. Carried.

Professor Huber introduced the following resolution:

RESOLVED: That the Association express its sincere appreciation to the Authorities of the United States National Museum for granting facilities and accommodations for the meeting, and to Doctor O. B. Hunter, of George Washington Medical School, and Dr. R. W. Shufeldt for many courtesies shown, the hospitable entertainment provided, and the microscopes furnished for demonstration purposes.

Unanimously carried.

On motion the Session adjourned.

CHARLES R. STOCKARD,
*Secretary of the Thirty-Sixth Session of the
American Association of Anatomists.*

ABSTRACTS OF PAPERS

1. *The relation of the smooth muscle in the hepatic veins to shock phenomena.* L. B. AREY and J. P. SIMONDS, Northwestern University Medical School.

Appropriate experimentation by one of us (J. P. S.) indicates that an obstruction to the flow of blood through the hepatic veins (not the splanchnic area, portal branches or intralobular sinusoids) is the underlying factor responsible for anaphylactic and peptone shock in dogs. Histological examination of the hepatic veins of the dog reveals a relatively enormous amount of smooth muscle in the wall, thus demonstrating an adequate anatomical basis for impeded vascular flow should spasm occur. The existence of actual spasm having since been established the correlation of structure and function in this instance is complete.

In the guinea pig and rabbit the manifestations of shock are different. The guinea pig shows violent dyspnea in which it receives air into the lungs but is unable to exhale it. It is known that in the guinea pig the finer bronchioles are essentially mere muscular tubes. It seems possible, therefore, that the variable reactions of animals to shock of this kind are dependent on the relative distribution of smooth muscle in the body. For this reason, a comparative study of the hepatic veins of mammals has been made to learn the extent of correlation in the distribution of smooth muscle among phyletic or other groups.

2. *Potentialities of different parts in the kidney anlage.* RUTH RAND ATTERBURY (introduced by Vera Danchakoff), Columbia University.

As known, the kidney is an organ developing entirely from mesoderm. Its epithelial part as well as its stroma have for their origin the primitive segment stalks of the somites. The epithelial tubules of the metanephros are derived from the inner zone of the metanephrogenic cord and the stroma from its outer zone. The mesenchyme or stroma of both meta- and mesonephros has been recently shown by Danchakoff to possess a hemopoietic potency, which before has been ignored in the embryo and denied in the adult. The renal epithelium of the metanephros, of which the mesenchyme has been transformed into granulopoietic tissue, was seen to continue to develop in the usual way without any apparent disturbance. The conditions of the experiment did not show whether the apparently specific development of the nephrogenic tissue into characteristic tubules of the kidney was due to the specific structure of the tissue or to the fact that the organ continued to develop in its usual environment. A fundamental change of the environment only could reveal in the nephrogenic tissue potencies different from those revealed under normal conditions, if it possessed them at all. The results of growing the adult kidney tissue upon artificial media by Champy seemed to show the process of development of the nephrogenic tissue to be more a process of specialization than of specific

differentiation. For Champy seemed to obtain in cultures a transformation of the mature epithelial kidney tubules into an undifferentiated mesenchymal tissue.

A series of experiments were undertaken in which the metanephric anlage of chick of six and seven days' incubation was grafted in toto and in parts upon the allantois of a seven-day chick embryo. The kidney anlage at the time of grafting (six to seven days' incubation) does not yet contain glomeruli and the differentiation process of the secretory tubules has not proceeded further than the stage of vesicle formation. Both the nephrogenic tissue proper and the mesenchymal anlage of the stroma survived and grew in the allantois. Those parts of the nephrogenic tissue which at six days' incubation have already received an epithelial arrangement proliferated and showed numerous mitoses. The less differentiated parts of the nephrogenic tissue, which at the time of grafting appeared in the form of a dense mesenchymal syncytium, have been seen to proliferate also and gradually to acquire an epithelial arrangement. The differentiation process went further and led to the appearance of structures which were not present in the grafted material. Glomerules developed in the kidney anlage grafted upon the allantois very much in the same way as they do in an undisturbed kidney anlage.

The mesenchyme of the anlage which provides the adult organ with its stroma, as mentioned above, grew and differentiated also in the graft, but it was seen to develop along lines different from those characteristic for the normal development of the anlage. Normally, the mesenchyme transforms into the very sparse stroma of the adult organ to which Maximov categorically denies a hemopoietic potency. In the grafts it transformed into large foci of granulopoietic tissue, thus once more confirming the equivalency and polyvalency of the loose embryonic mesenchyme.

3. The development of the human hypophysis. WAYNE J. ATWELL, Medical Department, University of Buffalo.

A careful study of the morphogenesis of the human hypophysis cerebri has been undertaken and wax-plate reconstructions have been prepared from 10-mm., 16-, 19-, 26-, 30-, 39-, 45-, 55-, 102-, 110-, and 177-mm. embryos and fetuses. The pars tuberalis or 'lobulus bifurcatus' of Bolk can be recognized in the younger stages and is then traced continuously to the oldest. It is shown conclusively that Herring's 'tongue-like process of the pars intermedia' is developed quite independently of the pars intermedia. Thus the name applied by Herring is misleading.

The pars intermedia, during development, sends a process dorsalward on each side of the neck of the neural lobe. These are not to be confused with the dorsal horns of the pars tuberalis (lobulus bifurcatus).

The pars tuberalis comes to lie in the pia mater under the tuber cinereum. It is thus separated from the remainder of the gland—except where attached—by the arachnoid spaces and the dura mater.

The epithelial lobe early becomes very broad from side to side. There is a distinct difference in this respect between the hypophysis of man and of certain other vertebrates, notably the rabbit. In the latter, which was made the subject of a previous study, the antero-posterior diameter is found to be the greatest. The 'cupping' of the epithelial lobe to form a fossa in each lateral half explains the bilateral connective-tissue cores seen in transverse sections of the adult hypophysis.

4. *The effects of inanition on the pregnant albino rat, with especial reference to the changes in the relative weights of the various parts, systems, and organs of the offspring.* LEE W. BARRY (introduced by C. M. Jackson), University of Minnesota.

Seventeen female albino rats were severely underfed (limited diet of bread and milk) from time of observed copulation for periods varying from 16 to 26 days. One only bore a litter. Fifty-nine females were similarly underfed from the eleventh day after copulation until delivery. Nineteen gave birth to litters; 12 died during underfeeding; and in 27 no litters resulted. No abortions or premature deliveries were observed. Death of the fetuses in utero occurred in three rats. Period of gestation varied from 21 to 26 days, averaging 23 days. Average number of observed young per litter was 5.9. Average weight of the new-born from the underfed mothers was about 3 grams (40 per cent below the normal birth weight of 5 grams).

The weight changes in the systems and individual organs in the new-born rats (tests, from underfed mothers) as compared with fetuses of the same body weight (controls, from normally fed mothers) showed the integument to have a weight 10 per cent above normal in the test rats, while the musculature and moist skeleton were slightly below normal weight; the dry skeleton was slightly above normal; while the viscera as a whole showed a weight 18 per cent subnormal. Of the organs, the spleen, eyeballs, epididymis, testes, and brain manifested the strongest growth tendency during prenatal inanition. The heart, kidneys, stomach, and ovaries showed a slight growth tendency. Retardation in growth during prenatal inanition occurred in the pancreas, spinal cord, intestines, thymus, thyroid, lungs, liver, and suprarenals.

5. *A study of the palmaris longus muscle in the living.* J. McC BATTIS and J. W. THOMPSON (introduced by C. H. Danforth), Department of Anatomy, Washington University School of Medicine.

The palmaris longus muscle is easily studied in the living. In most cases its size, position, and method of insertion can be accurately determined. A considerable range of variation is to be noted. The variations are apparently more numerous in white than in negro subjects. Absence of the muscle proves to be an hereditary trait. There is some indication that other variations in this muscle are also hereditary.

6. *The adult sitting height.* R. BENNETT BEAN, University of Virginia.
Data: 2016 white soldiers, 1271 negro soldiers, 50 white teachers, 598 Filipino men, 63 Filipino women.

The sitting height in terms of the stature as 100, called the skeletal index, is shown to vary with stature, sex, race, and type.

The skeletal index is inverse to stature, less in the tall than in the small.

The skeletal index is greater in the female than in the male.

The index is the same in the white and Filipino, but less in the negro. The trunk of the negro is greatly curved thus making the trunk absolutely and relatively short, which accounts for the low index in this race. The white is taller than the Filipino and therefore should have a smaller index, but the Filipino has a large amount of negro (negrito) mixture, with the hypophylomorph and mesophylomorph type; the low stature and the two types with a high index, neutralize the negro stock with a low index, therefore the index of the white and Filipino are the same.

The differences due to type are significant. The hypophylomorph has a high index, the mesophylomorph an intermediate index, and the hyperphylomorph has a low index. Of the three subtypes in each of these the super has a low index, the inter has an intermediate index, and the sub a high index. The index is different with persons of the same stature but of a different type.

Finally, the sitting height, and therefore the leg length are dependent not only on growth, but also on metamorphosis.

7. *The sitting height in children.* R. BENNETT BEAN, University of Virginia.

Data: 1445 white children of Ann Arbor, Michigan; 776 Filipino children of Manila, Philippine Islands.

The skeletal index decreases from birth to maturity because the lower extremities grow faster than the trunk.

Between the ages of 10 and 16 in American boys and 8 and 16 in German-American boys the index is less than before and after, because the extremities are growing more rapidly at that time.

The subsidence of the accelerated growth of the extremities appears earlier in the Filipino boys than in the other two groups.

The period of accelerated growth of the extremities occurs between the ages of 9 and 14 years in American girls and 8 and 12 in German-American girls. There are too few Filipino girls for comparison.

The skeletal index is greater at all ages in the girls than in the boys, and this difference is more marked among the Filipinos than among the whites.

A marked difference between the types is noted among the American boys, where the subhyper has a high index, the interhyper an intermediate index, and the superhyper a low index. This is not so marked among the German-American boys, where race may overshadow type, neither is it so marked among the girls of all the groups, where sex

seems to overshadow type. The index of the hypo is about the same as that of the hyper among the Filipino boys, due to the negrito stock, and the meso is higher than either.

8. *On the normal occurrence of a fenestra in the cloaca of chick embryos.*

EDWARD A. BOYDEN, Harvard Medical School.

In reviewing the development of the cloaca in the bird, a number of interesting features have come to light which apparently have not been recorded before. The most striking of these is the regular appearance, during the third day of incubation, of an aperture in the dorsal wall of the cloaca, produced by degeneration of the epithelium and its subsequent removal by macrophages, so that for a period of about twenty-four hours the contents of the cloaca are in contact with mesenchyma. This process of disintegration and removal, as observed in eighteen embryos of the Harvard Collection, begins in the ventral wall of the postanal gut where the latter joins the cloaca and spreads rapidly in two directions,—caudally up the postanal gut into the tail, and cranially along the sides of the cloaca, irregularly perforating both structures so that the walls have the appearance of fenestrated membranes. Within twelve hours the postanal gut has disappeared from the proximal half of the tail, and a continuous gap has been produced in the adjacent wall of the cloaca. At first the contiguous mesenchyma is slow to react, but after an interval it sends sprouts into the exposed portions of the cloacal cavity. The gap in the cloacal epithelium becomes closed during the next twelve hours by the approximation of right and left dorsal walls which finally fuse to form a solid cloacal membrane. Subsequently the dorsal margin, which represents the fused lips of the fenestra, proliferate to form a vacuolated diverticulum, the bursa of Fabricius. One of the most striking features of the whole process is the great activity of the macrophages. Not only are they removing the disintegrated epithelium, but also the undifferentiated tailbud mass close by, and portions of the sacral myotomes. Attention was called a year ago to the activity of embryonic phagocytes in removing vestigial gill filaments and portions of the optic stalk and cup in chick embryos of corresponding age. These combined observations would seem to emphasize the importance of the rôle which the macrophages play not only in such later periods of development as are represented in the metamorphoses of larvae, but in the very early stages of organogeny.

9. *Recurrent branches of the abducent nerve in human embryos.* J. L. BREMER, Harvard Medical School.

Although these branches have been known for a number of years and have been mentioned in a few books of embryology, they are not considered generally to be more than infrequent anomalies. Examination of the human embryos up to 22 mm. in this laboratory shows that these branches are present in a great majority of the cases and should therefore perhaps be considered a part of normal development.

They disappear from 18 mm. onward, the trunk occasionally remaining separate from the root, and therefore disconnected from the brain stem. Large sizes of these nerves in certain cases should be noticed. They are not so prevalent so far as I know in any other type of mammal.

10. *Differential growth forces as stimuli to intestinal histogenesis.* EBEN J. CAREY, Creighton Medical College.

The dominant and most active region of growth in the intestine is the epithelial tube; the less actively growing zone is the surrounding mesenchyme. In the descending colon of the pig the epithelial tube grows caudocephalad. The mitotic figures follow primarily the path of a left-handed helix. In one embryo of the thirty examined a right-handed helix was described. This consequently leads to a gradually increasing diameter in a spiral manner comparable to the rifling within the barrel of a Winchester rifle.

In pig embryos 10 to 25 mm. in length the descending colon grows relatively more rapid in diameter than in length. In embryos 25 to 45 mm. in length the descending colon grows relatively more rapid in length than in diameter. As the epithelial tube begins to increase rapidly in diameter by the left-handed spiral boring of the mitotic divisions, the peripheral mesenchymal cells are thrown into close spirals, resembling rings, by the centripetal force of the growing epithelial cells. During the period of active growth of the epithelial tube in diameter the inner smooth muscle coat, apparently circular but in reality a close spiral, is formed.

Concomitant with the formation of the inner close spiral musculature there is resistance to epithelial tubular growth in diameter. The epithelial tube, pursuing the lines of least resistance, now grows in length. This results in rapid elongation of the descending colon. A stretching of the undifferentiated cells is produced peripherad to the inner close spiral muscle coat. This leads to the differentiation of the outer apparently longitudinal muscle coat, but in reality forming an elongated open spiral, corresponding to the epithelial tubular growth.

11. *Differential growth forces as stimuli to bone and muscle origin.* EBEN J. CAREY, Creighton Medical College.

The most rapidly growing element of the developing limb is the central core which subsequently forms the skeleton; the least actively growing part is the surrounding mesenchyme which subsequently develops into the musculature and related connective tissues. These two zones of differential growth exert an influence upon each other which is objectively evident by an alteration in the external form and internal structure of the cells involved.

Newton's third law of motion that action and reaction are equal, opposite, and simultaneous is equally applicable in organic development and in the inorganic world. This law is deduced from demonstrable evidence in the growing limb.

As the skeletal core rapidly grows in length it exerts a tractional force on the continuous syncytial mesenchyme resulting in an elongation of the latter. The mesenchymal nuclei, cytoplasmic granules and myofibrillae are drawn out in the direction of skeletal growth. The reacting tensional stresses elicited in the mesenchyme and embryonic musculature causes a retardation in the rate and direction of growth of the skeletal tissue. This leads to progressive condensation and hardening of the skeleton in reacting to the developing and physiologically active musculature. The condensing skeleton in turn as it continues in rapid growth tends to split the former indefinite premuscle masses into the definitive muscles. Concomitant with this cleavage the form of the skeletal elements becomes more clearly outlined, due to the definite application of the forces of the individual muscles.

The osseous material is first economically distributed at the periphery, on the convex weaker aspect of the bent femur. Later the bone encircles the shaft and appears on the concave compressive side of the bent cartilaginous femur.

There is clearly evident a mutual interaction between the developing skeleton and the musculature which is produced by the forces of differential growth.

12. Causes and results of the spiral growth of the alimentary epithelial tube. EBEN J. CAREY, Creighton Medical College.

The spiral course of the epithelial mitotic path is due to two factors: first, a translatory motion imparted by the caudal rapidly growing part of the colon, and, second, a rotatory motion produced by the resistance of the inner curved surface of the mesenchymal wall which constantly deflects the rectilinear motion of growth in a curved manner.

A body in motion tends to pursue a straight line unless acted upon by some extrinsic body. A growing body also tends to follow a straight path, but the resistance of related continuous zones in a less active state of growth causes a deflection of growth from the rectilinear path. The antagonistic forces of differential growth, therefore, are active in the production of spiral growths.

The subsequent rotation of the stomach and the characteristic intestinocolic spiral loop are resultants of the predominant left-handed spiral growth of the epithelial tube.

13. A note on the structure of the contractile vacuole in Amoeba proteus.

ROBERT CHAMBERS, Cornell University Medical College.

By means of the microdissection needle the contractile vacuole may be readily cut in two within the body of the amoeba. The two resulting vacuoles, on coming into contact, readily run together to form a single spherical drop. If they be kept separate, each one grows in size and undergoes normal pulsating phenomena.

If a contractile vacuole be dissected out into the water, it maintains its spherical shape and exhibits a sharply defined margin. It may be rolled about without being destroyed. Very soon, however, it begins

to contract, steadily diminishing in size until its surface film wrinkles up into a collapsed membrane-like remnant.

This experiment indicates that the contractile vacuole possesses a morphologically definite membrane which collapses when the contents are extruded. Within the body of the amoeba the membrane is fluid enough to be easily subject to surface-tension phenomena so as to allow two contiguous droplets to fuse. When surrounded by water, the membrane has a tendency to persist.

14. *The fertilization membrane of the starfish and of the sea-urchin egg.*

ROBERT CHAMBERS, Cornell University Medical College.

Full-sized immature and mature starfish eggs possess a cuticular membrane which adheres tightly to the egg surface and which may be torn off in strips by means of the microdissection needle. In the mature egg this membrane is tougher than in the immature. Very young ovarian eggs possess no such cuticle.

In the mature sea-urchin egg no such membrane can be detected. The egg is naked except for a surface film of a slightly jellied consistency.

This difference in the starfish and sea-urchin egg is strikingly demonstrated when the eggs are cut in two by means of a horizontal needle pressed against the side of the egg. In the starfish egg the extensible cuticular membrane is not cut through in the process and the two pieces of the egg are therefore held together. In the sea-urchin egg the two pieces drop away from one another, there being nothing to hold them together.

15. *The ineffectiveness of churning the content of an egg on its subsequent development.* ROBERT CHAMBERS, Cornell University Medical College.

The mature unfertilized Arbacia egg is a mass of very fluid protoplasm surrounded by a surface film of a slightly jellied consistency. One may tear a needle back and forth from one side of the egg to the other without cutting it in two, as the gap so produced quickly closes behind the advancing needle.

Besides this, thorough churning movements can be induced within the egg. If an egg be kept under a slight compression while it is being pushed with the end of a blunt needle, cytoplasmic currents are produced flowing away from the needle through the center of the egg to the opposite pole where they spread out over the surface of the egg and flow back to the point where the needle touches the egg. In this way the entire mass of the egg is thrown into vortical currents flowing through it and all over its surface.

This together with the tearing movements must completely derange all preexisting spatial relations of the protoplasmic constituents. An egg treated in this way is still readily fertilizable and develops in a normal manner.

Any readjustment of materials within the egg for the maintenance of its normal polarity may be brought about by the development of

the asters which precede segmentation rather than by making the assumption recently put forward that there exists a viscid structural network pervading the egg. In the formation of the aster currents are induced which flow toward the center of each aster. This is accompanied by a spreading from the astral centers of something which sets the protoplasm into a jelly-like mass. These changes which always must occur to insure segmentation may be sufficient to explain any readjustment that is necessary to preserve polarity.

16. *The character of the lymphatics in experimental edema.* E. L. and E. R. CLARK, University of Missouri.

Edema was produced in tadpoles: 1) by removal of the pronephros; 2) by removal of the blood heart anlage; 3) by prevention of the development of the lymph heart musculature, and, 4) in connection with aseptic inflammation.

1. With pronephros removed, fluid collects only in the abdominal cavity. Blood circulation is embarrassed and blood vascular development retarded. The lymphatics develop and apparently function normally.

2. With blood heart removed, edema is confined to the body cavities. Lymphatic capillaries in the tail are slightly larger than normal.

3. In tadpoles without a beating lymph heart, large amounts of fluid collect in the head sinuses, and eventually in the subcutaneous tissue of body and tail. Lymphatic capillaries become much distended.

4. In inflammatory edema, the lymphatic capillaries of the injured region become distended.

In chicks the development of the lymph heart was prevented by cutting off the tail in three-day embryos. At seven days the embryos are edematous. Injection shows the presence of distended, sac-like lymphatics, instead of the much smaller ducts present in normal embryos.

Conclusions: 1) Lymphatic capillaries develop normally and absorb lymph with the blood circulation hampered or absent. 2) When the outlet of fluid from the lymphatics is interfered with they become distended. 3) Collection of fluid in the tissue spaces is associated with enlargement of the lymphatic capillaries. This result is the opposite of the view generally held by pathologists, that lymphatic capillaries are collapsed in edema.

17. *The reaction of cells in the tadpole's tail to injected croton oil, as seen in the living animal.* E. R. CLARK and E. L. CLARK, University of Missouri.

Microscopic globules of croton oil, diluted with paraffin oil, were injected into the fin expansion of the tail of young *Hyla* larvae, and the resultant 'aseptic inflammation' watched in the living animal. The point especially studied was the question whether, in inflammation, cells of one type remain specific or are transformed into other types of cells. The general picture was first obtained, and then the different

types of cells studied intensively. It was found that leucocytes and wandering cells of the tissue spaces move toward the croton oil, but do not reach it. They stop a short distance away and become stationary, throwing out many pointed processes, until they resemble small connective-tissue cells. They do not become connective-tissue cells, however. Instead, they later become spherical, and, after some hours or days, resume amoeboid activity, and move away, the oil, in the meantime, having been extruded. Connective-tissue cells, near the oil, become granular, then swollen and vacuolated, and a few cells die. Most of them recover, after the oil is extruded, and resume power of motility. Blood capillaries show endothelial vacuolization and retraction, followed by new growth. Lymphatic endothelium responds similarly.

All the types of cells remain specific throughout. Wandering cells do not form from endothelium or from connective-tissue cells, nor do they give rise to either of these tissues. Connective-tissue cells and blood and lymphatic endothelium likewise remain specific, and are not converted into nor derived from other types of cells.

18. *The nervous nature of the floor plate in the neural tube of Amblystoma.*

G. E. COGHILL, Department of Anatomy, University of Kansas.

In *Amblystoma* embryos of the non-motile stage cells that present all the characteristics of neuroblasts occupy the floor plate in large numbers. As many as 366 have been found in a single specimen, distributed from the cephalic flexure caudad throughout the medulla oblongata and the spinal cord. Their nuclei are among the largest in the nervous system at this time. Many of them are scarcely broken away from the epithelial arrangement in the ependyma; others have a distinctly bipolar, broadly fusiform shape. All are densely crowded with yolk. Occasionally fibrils appear in their protoplasm, but no fibrillar processes issue from them in non-motile embryos. As soon in development, however, as crossed reflexes appear in response to localized tactile stimulation, fibrillae, staining like spindle fibers and running in general longitudinally in the cells, converge into densely fibrillar processes. These, spanning the floor plate, establish the first commissural relation between the basal plates of the two sides and make possible the first crossed reflexes which characterize the early behavior of these animals.

That these nerve cells belong actually to the floor plate and do not migrate into it from some other source is obvious from the fact that many of them that have the distinct nuclear characteristics of neuroblasts still retain their ventricular attachment among the ependymal cells. Furthermore, the cells of the floor plate at this time are proliferating rapidly and there is a distinct correlation between the processes of proliferation and differentiation throughout this region,—the neuroblasts being more numerous where the mitotic figures are less abundant, namely, in the medulla oblongata and in those regions of the cord which are destined to control the limbs and their girdles. This

feature of distribution suggests a functional relation of these floor-plate cells to the limbs, but nothing is known of their history beyond the time when the embryo begins to swim. That they can be regarded as a distinct type or group of neurones is doubtful. It is more probable that they are simply the median portion of a single primordium that includes the ventral portion of the basal plates of the two sides. Upon the latter hypothesis one may consistently think of an ancestral, pre-tubate central nervous system of which the median portion was an homogeneous somatic motor column.

19. On abnormalities of the pig embryo occurring before attachment to the uterus. GEORGE W. CORNER, Johns Hopkins Medical School.

During the collection of a small series of very early embryos of the pig, a few have been found which show various degenerative changes and abnormalities of growth, occurring before the age of two weeks, at a time when the blastodermic vesicles are not yet attached to the uterine mucosa. These specimens taken in conjunction with the larger series reported by Huber (Mem. Wistar Inst. no. 5, 1915) indicate the probable occurrence of exceptions to Mall's rule that all pathological mammalian embryos are due to faulty implantation.

20. The reaction of peritoneal mesothelium to granular suspensions and laked blood. R. S. CUNNINGHAM, Johns Hopkins Medical School.

In studying the reactions of the mesothelial cells lining the diaphragm to substances introduced into the peritoneal cavity two phases of activity have been observed. These cells respond immediately to suspensions of carbon and carmin by ingesting the particles in large numbers and in turn rapidly discharging them into the intercellular spaces and adjacent lymphatics. This phagocytic activity is very great because of the large cellular area exposed and the mechanical assistance rendered by the movement of the diaphragm.

When exposed to granular suspensions for a period of several days, this being accomplished by repeated injections, these cells change from the characteristic flattened pavement type to cells cuboidal in shape with large oval nuclei and more abundant cytoplasm. Throughout the time of exposure they continue to phagocytize particles of the injected material. If, instead of granular suspensions, laked heterogeneous blood be used, the change is even more striking; the cells not only increase greatly in size, but round up as if preparing to separate from the tissue to which they are attached.

After ten days' exposure to lake blood, when the maximum change has taken place, if carmin or carbon particles be introduced, they are still rapidly phagocytized by the enlarged mesothelial cells.

Cats were used for these experiments and rabbits as donors for the blood.

21. *Developmental and functional potencies of the mesenchyme.* VERA DANCHAKOFF, Columbia University.

The experimental proof of the equivalency of the hemopoietic anlagen, the loose mesenchyme inclusively, has been recently brought forward by producing their simultaneous granuloblastic transformation. A few new findings relating to the granuloblastic transformation of the stroma of the kidney, ovary, testis, and muscles will be illustrated by lantern slides from photographs.

How far the adult mesenchyme in general retains the power of further differentiation is not yet definitely determined. The adult mesenchyme of the chick spleen at least may intensely proliferate and differentiate further, as will be shown by lantern slides from retouched photographs. Both properties, proliferation and differentiation, are characteristic of young embryonic tissues. A series of lantern slides will demonstrate another capacity highly characteristic of embryonic cells and mesenchymal adult cells as well.

The intracellular digestive power of isolated mesenchymal cells over dead protein has been observed and often described. A digestive capacity of adult mesenchymal cells over living tumor cells of the Ehrlich sarcoma is the object of the present demonstration. It is known, that the protoplasm of our various tissues acquired new properties of contractility, conductivity, and secretion by special changes taking place in their economy. A great many of our tissues lost thereby their power of proliferation, of further differentiation, and also of digestion. Highly specialized in their function, they maintain their metabolism at the expense of various amino-acids always present in abundance around them. It is only the so-called connective-tissue stroma, to which only a passive function of supporting other tissues has been yet attributed, which fails to show differentiation of its cytoplasm. If a fibroblast develops collagenous fibers, they are cast off outside. This tissue, as we begin to see, has maintained itself through the various epochs of the individual life but little changed. Just as in embryonic life under definite conditions it may develop into a series of various specific cells, so in adult life it is capable of differentiation into the same products, if brought under the same conditions (spleen in the allantois). It proliferates readily wherever it is found in the adult organism under conditions called in the adult organism abnormal. But what might prove to have a bearing upon the resistance of the organism against heteroplastic grafting the connective-tissue cell does not lose its digestive power, it exhibits it over dead protein of its own kind and over some living tumor cells, as illustrated by lantern slides. The mesenchymal cell of the adult organism retains its digestive power over the dead protein of its own kind from embryonic time, the capacity of killing and digesting a living tumor cell seems to be a property acquired in chick after birth.

22. *Hemopoiesis in the embryonic mesenchyme of chick.* VERA DANCHAKOFF and MAURICE RICHTER, Columbia University.

Hemopoietic centers in the embryonic loose mesenchyme have been described by Maximoff, Danchakoff, Miller, and Regan. A diffuse development of wandering cells and granulocytes as well as the appearance of foci of erythrocytes in the midst of loose mesenchyme have been observed by them, and it has been practically unanimously admitted that erythropoietic centers were situated in the loose mesenchyme extravascularly. Even in chick, in which the erythropoiesis is throughout lifetime of the animal intravascular, extravascular foci of erythroblasts may be observed in certain regions of the embryo body. It would seem, therefore, that the intravascular position of a hemoblast would not be a necessary factor, even less a determining factor, in the erythropoiesis, as has been surmised by one of us.

A restudy of the development of the extravascular erythropoietic foci in chick has, however, revealed a strong dependency of the erythropoietic differentiation of the hemoblast within the loose mesenchyme upon some factors found within the vessels. Lantern slides will illustrate the process of development of blood-island-like formations around the aorta and the coeliac artery, the formation by the mesenchyme of endothelial sheaths around these cell clusters, and the incorporation of such newly formed vascular channels into the circulation. Not until a communication of the newly formed channels, which contain a great number of hemoblasts, with general circulation is established, do the hemoblasts differentiate into erythroblasts. The vascular network in the particular zone is characterized by a great irregularity and changeability. New clusters of isolated hemoblasts develop in this zone at from four to seven days of incubation; they are surrounded by mesenchymal endothelium which soon joins a loop of a capillary or a larger vessel, even the aorta, as seen in one of the lantern slides. If the cells within the newly formed vessels are removed by the established blood current, the channel may collapse and soon new ones are formed. Segments of channels containing hemoblasts and erythrocytes are readily cut off and then the endothelial cells are seen to loosen themselves and mix with the surrounding mesenchyme. Groups of erythroblasts, now free in the mesenchyme, continue to proliferate and differentiate into erythrocytes, though never do the erythrocytes under these conditions elaborate as much hemoglobin as under ordinary conditions. The extravascular erythropoietic foci around the aorta and the coeliac artery do not develop primarily from mesenchymal cells outside the vessel, but, as generally established for the hemopoietic organs of the birds, from hemoblasts which began their erythropoietic differentiation within the vessels. If, on the other hand, the formation of an endothelial wall around a group of hemoblasts has been delayed, all of the hemoblasts undergo a granuloblastic differentiation and all of them may be later incorporated into a vascular channel and continue to proliferate further.

At a later stage one may find in this region erythropoietic foci outside the vessels and groups of granuloblasts may be contained within channels surrounded by endothelium. A detailed study of their origin and development shows, however, that, as elsewhere, the polyvalent hemoblast develops into an erythroblast, only if it is submitted to intravascular conditions and that a granuloblast can start its differentiation only outside the vessel.

23. *The relation of the somites of the head to the brain in a human embryo of twenty paired somites.* CARL L. DAVIS, University of Maryland.

In an embryo of twenty pairs of somites (no. 2053, Carnegie Embryological Collection) the rhombencephalon consists of nine folds or grooves. Craniocaudally they are, first, the cerebellar; next, a series of six folds related to the ganglia of the fifth, seventh, eighth, ninth, and tenth cranial nerves and which I have termed the branchial grooves, and, lastly, the eighth and ninth folds from which the accessory nerve will be derived.

The first somite is rudimentary. Its cephalic extremity lies lateral to the junction of the last branchial groove with the eighth rhombic fold and extends caudally over the cranial half of the latter. The second somite is lodged opposite the junction between the eighth and ninth rhombic grooves, while the third somite lies lateral to the sulcus between the last rhombic groove and the beginning of the spinal cord.

24. *The erythrocytic and leucocytic elements in the blood of *Batrachoseps attenuatus*.* VICTOR E. EMMEL, Department of Anatomy, University of California.

In the course of a previous study of the origin of non-nucleated erythrocytes in mammals, attention was directed to the question of the presence of similar elements in *Batrachoseps attenuatus* (Am. Jour. Anat., vol. 16, p. 180). In contrast to all vertebrates other than mammals, the blood of this amphibian is characterized by the occurrence of a remarkable number of non-nucleated erythrocytes together with certain free cytoplasmic elements comparable to blood-platelets. This unique deviation, phylogenetically, from the morphological elements typical of the blood of the lower vertebrates emphasizes the importance of a more thorough knowledge of the hematological conditions occurring in this animal. The present paper will present the results of a study of the structural characteristics and origin of the non-nucleated erythrocytes together with comparisons with erythrocytic conditions occurring in mammalian blood, data regarding the origin of the free cytoplasm elements or blood-platelets, certain cytological characteristics of the eosinophiles as compared with other vertebrates, the behavior of the mast cells in the circulating blood, and in cooperation with one of my students, Mr. Haight, a differential count of these various cellular elements. In correlation with these hematological conditions is to be discussed a deficiency in the respiratory system consisting of apparently an entire absence of lungs.

25. *Bladder epithelium in contraction and distention.* O. H. GAEBLER (introduced by E. R. Clark), University of Missouri.

The problem considered in the work reported in this paper is the following: Does the epithelium of a distended bladder contain fewer layers than that of a contracted bladder? Do the cells, as some observers say, 'slip by one another' and form fewer layers during distention?

This problem is approached in two ways: first, to avoid the tangent sections inevitable in the extensively folded epithelium of completely contracted bladders, bladders are secured that have normally contracted just to the point where folds begin to form. Of such bladders sections can be obtained that run normal to the epithelium, just as carefully prepared sections of distended bladders do. The layers in the contracted and distended bladder are then counted directly.

Secondly, it is observed that if all stretching of the epithelium is to be accounted for by stretching of the cells, and not by slipping, the ratio representing the stretching of the epithelium should be the same as the ratio representing the stretching of the cells. These ratios are determined, the determination of the latter one involving six thousand cell measurements in six rabbits of the same litter.

The results of both methods show that there is very little, if any, 'slipping' of cells, and that the stretching of the epithelium is accounted for by stretching of the cells.

26. *The free granules (Chylomicrons) of fresh blood as shown by the dark-field microscope, and their dependence upon the kind of food ingested.* S. H. GAGE, Cornell University.

As pointed out by Dr. James Edmunds in 1877, with the dark-field microscope, using an immersion objective and an immersion paraboloid, blood appears as a new object. "The serum is seen filled with a nebulous haze of points as is mote-laden air in a sunbeam." And from the increased visibility, this method of study gives a definiteness to the microscopic image that can only be appreciated by comparing the same specimen of blood under the dark-field and then under the bright-field microscope.

Repeated observations brought out the fact that the free granules in the blood varied greatly with the same individual. Fasting experiments proved that their presence in the blood was dependent upon the ingestion of food. Experiments with the three great types of food, singly and in combination, demonstrated that it was neither proteid nor carbohydrate nor their combination, but the fat alone that determined the presence of the free granules, and that they appeared in the blood when pure fat was ingested or when it was taken in combination with either carbohydrate or pure proteid, or with both carbohydrate and proteid food.

The conclusions are that blood examination will show with certainty: *a*) whether fatty food is digested and absorbed; *b*) the comparative digestibility of fats with a given individual, and with different individuals and animals; *c*) the time required for digestion and absorption, *d*) whether a given fat or oil is digestible.

The term Chylomicron has been selected for these bodies, because it may be used both in the singular and the plural, and it is significant, giving the source and the size of the bodies.

27. *A graphic reconstruction method for the study of injuries to cochleae.*

STACY R. GUILD, University of Michigan.

Most observers have reported cochlear injuries by written protocols, making only rough estimates of the relative lengths of injured portions, usually in terms of approximate parts of turns, without evaluation of lengths of various turns. Better interpretation of results is permitted by the author's former method of charting the organ of Corti as a straight band with the relative lengths of the various half-turns approximated, but the location of the ends of given injured areas was only guessed at, since the linear value of the parts of a curved structure contained in radial, oblique, and tangential sections varies. The graphic reconstruction method here presented evaluates directly the approximate lengths of all portions of the organ of Corti when cut in serial sections. It is the method referred to previously, but which was not used in the detonation protection problem because of the large permissible error on this point and the need for speed then. On ruled paper each space represents a section; the limiting sections for each half-turn are determined, and a series of semicircular lines drawn connecting points thus found; this forms a 'spiral-like' curve making approximate allowance for variations in linear values of different sections. This is the base line for charting. It is realized that the half-turns are not true semicircles, and that no allowance is made for the 'upward' (basi-apical) distance traversed. The more accurate data secured by this new method may be transferred to straight-line charts, as previously used, to facilitate comparison of numerous observations. A completely accurate projection of the organ of Corti onto a plane surface can be made only by a long series of very involved formulae based on numerous three-dimensional point determinations. Wax reconstruction gives spatial relations better than any graphic method, but is not practicable to use routinely for the number of cochleae needed in experimental injury work.

28. *The digestion tract of the opossum at birth.* CHESTER H. HEUSER, Johns Hopkins Medical School.

As the intra-uterine period in the opossum is only of thirteen days' duration, the intestinal nutrition commences while the animal is still relatively immature. In a collection made while at The Wistar Institute, the youngest specimens found in the pouch, not more than a few hours old, contained milk in the stomach; the milk could be seen through the body-wall of the living animal.

The stages considered here are the embryos just before birth and the pouch-young about three days old. A striking feature of the intestine of the opossum embryos is the presence of numerous large sinuoidal vessels which closely hug the mucosa. In the pouch-young

especially the wall of the intestine is extremely thin; the mucosa, moreover, makes up nearly the whole thickness. There are large, tall villi covered by columnar cells containing masses of granules in their distal ends. There is no evidence in these specimens of the development of glands.

In the early pouch-young at least, the movements in the intestines must be very feeble; a few myoblasts only can be identified, but a distinct muscular coat is practically absent. The first coils of the small intestine have a much longer girth than the rectum, indicating that but little food-residue is passed on to it.

The constitution of the maternal milk is not known, but it is possible that it contains elements which compensate for the primitive condition of the digestive tube and the accessory digestive glands.

29. *Radiography applied to the teaching of topographical anatomy.*

JAMES A. HONEIJ and HAROLD S. BURR, Yale Medical School.

Additional methods for the teaching of topographical anatomy are undoubtedly needed. The method which is presented here has been applied by others in a meager manner along special lines of work and to some extent in research. By injecting the arterial system and then radiographing the body in sections, both before and after the internal organs have been removed, information of value has been obtained. The organs themselves are radiographed. Tracings are then made of the radiograms, and these as well as the radiograms themselves compared with dissection.

Topographical anatomy enables the student to acquire a clear, visual image of all structures underlying any given area of skin in their proper relations. This can be accomplished in several ways. Usually it is done by means of cross-sections and comparison with longitudinal sections, or it can be done through the study of so-called normal radiograms accompanied by outline tracings, and, lastly, through a study of radiograms of a body whose arterial system has been injected.

Such radiograms will show the position and size of the organs, their circulation, the caliber of vessels, and their anastomosis. For studying parts of the body and organs which are difficult of dissection and where the relations are difficult to retain, the radiograms are of great assistance.

A better understanding of the pathological and physical processes can be had by this method. We have effectively demonstrated this.

We have made an atlas giving radiograms, tracings, and descriptive texts of the body and internal organs which is now in the hands of the Yale Press. Ten slides and descriptions.

30. *Homöogenesis in the pulmonary evolution of the mammalia.* GEO. S. HUNTINGTON, Columbia University.

A comprehensive survey of the pulmonary architectonic types encountered in the mammalia permits of their division into three general groups:

1. The vast majority of forms exhibit pulmonary asymmetry, with the cranioventral segment of the right lung constituting the same the dominant and more effective organ, based on the additional respiratory extension acquired by the neomorph right eparterial bronchus. This condition represents the evolutionary stage of the respiratory apparatus attained by at least 95 per cent of the extant genera in common, no matter how widely diversified they may be in other portions of the structural organization.

2. In contrast to this dominant mammalian type a numerically limited group of mammalian lungs occupy at the present a lower evolutionary level, in which the pulmonary type still retains archeal lines derived from the reptilian ancestry.

3. The third group is composed of forms exhibiting in their pulmonary organization the result of specialized adaptations to functional and environmental factors, affecting directly the respiratory exchange. Within this group occur the examples of Homöogenesis, in which during the phylogeny identical morphological characters develop independently in groups differing in their line of phyletic descent and producing the appearance of evolutionary convergence. The present paper deals with some recent observations bearing this interpretation.

31. *A series of diagrams explanatory of the development of the postcava in the cat, with especial reference to the share taken by the supracardinal system of veins.* G. S. HUNTINGTON, Columbia University, and C. F. W. McCLURE, Princeton University. Presented by C. F. W. McClure.

This investigation was begun in 1905 with the purpose of determining in detail the normal ontogenetic venous plan which would serve as a basis for explaining the variant conditions observed in the adult cat resulting from an arrest in development of the veins.

The diagrams are based on a large series of reconstructions of the veins, made after the method of Born, of cat embryos ranging between 5 and 45 mm. in length. They are explanatory of the normal course of development of the postcava and its main tributaries as observed in the cat and, with only slight modifications, relating to the degree of development attained by certain embryonic veins, will serve for the conditions we have also observed in man.

Following are some of the more important features treated by us concerning the development of the veins:

1. The manner in which the pars hepatica of the postcava establishes its connection with the right subcardinal vein.

2. The postrenal division of the postcava is derived exclusively from the right side of what we have designated as the renal collar (circum-aortic venous ring at renal level) and from the supracardinal veins. No portion of the postcava is derived from the postcardinal veins as is ordinarily described.

3. The presence of two renal veins in the embryo which arise on each side from the renal collar.

4. A new interpretation of the development of the sex veins in which they conform to the conditions found in the lower vertebrates where they are derivatives of the subcardinal veins.

A composite diagram is also shown combining all of the venous pathways which may arise during ontogeny.

By means of this diagram it is possible to interpret the variant conditions of the postcava thus far observed in the cat and man.

32. *A physico-chemical interpretation of the histologic alterations in the contracting sarcomere.* H. E. JORDAN, University of Virginia.

The manner of development of the sarcostyle of the wing muscle of the wasp marks this element as the homologue of the myofibril of vertebrate striped muscle. In further attempts, therefore, to formulate an hypothesis of muscle contraction in conformity with histologic data, we may legitimately restrict our attention to the relatively very coarse sarcostyle of wasp's wing-muscle. This sarcostyle is composed of very minute 'metafibrils.' In the development of cross-striations the telophragmata precede the dim discs. The telophragmata may be conceived as the pathways along which enter the substances for the formation of the dim discs, and along which subsequent metabolic exchanges are effected. The dim disc contains potassium (Macallum, '05), certain chlorides and phosphates (Menten, '09); therefore ionizable crystalloids. These inorganic salts pass from the region of the mesophragma to that of the telophragma during contraction (Menten). The dim character and the deeply staining capacity of the Q-disc of the resting fiber, and of the contraction band of the contracted fiber, may be due largely to the presence of these electrolytes. The sarcomere consists essentially of a colloidal gel, with ultramicroscopic colloidal particles. If we postulate an original ellipsoidal shape of these particles, the shortening and thickening of the sarcomere during contraction may be explained as the result of a change in shape of the particles to spherical form, due to an increase of their surface tension following a decrease of surface electrical charges, in consequence of the passage of charged ions, at the instant of stimulation, from the mesophragma to the telophragma.

33. *Induced testicular degeneration and accompanying hypertrophy of the interstitial tissue.* ALBERT KUNTZ, Saint Louis University School of Medicine.

Bilateral degeneration of the seminal epithelium accompanied by hypertrophy of the interstitial secretory tissue following elimination of the sympathetic nerve supply to the testes in one series, and unilateral vasectomy with ligation in another series of dogs was previously reported. Further studies on a third series of dogs and a series of rabbits substantiate the conclusion that hypertrophy of the interstitial tissue in the testis occurs more promptly as an accompaniment of degeneration of the seminal epithelium than as a compensatory process. Animals unilaterally castrated and allowed to live, following operation, as

long as those which showed marked hypertrophy of the interstitial secretory tissue accompanying degeneration of the seminal epithelium showed no apparent change in the interstitial tissue in the testis left in situ unless degeneration of the seminal epithelium also occurred.

In the present series of dogs, as in the series previously reported, bilateral degeneration of the testes followed unilateral vasectomy with occlusion of the duct. In the rabbits of the present series the testis on the unoperated side showed no evidence of degeneration.

34. *The cerebellum of Amblystoma.* O. LARSELL, University of Wisconsin.

The cerebellum of *Amblystoma* is of primitive type, but shows some interesting features. There are present in simple form three layers which correspond in their general characteristics with the granular, Purkinje cell, and molecular layers of higher vertebrates.

A mass of cells with pretty well-defined boundaries rostrally and dorsally, but continuous with the tegmentum ventrally and caudally, appears to represent the beginnings of the dentate nucleus.

The fiber-tract connections are relatively simple.

35. *The weights of the viscera of the turtle (Chrysemys elegans).* HOMER B. LATIMER, University of Nebraska.

Twenty-two specimens supplied by a Chicago dealer were used. The turtles were chloroformed and weighed and then the viscera were dissected out and immediately placed in glass-stoppered weighing bottles and weighed to a tenth of a milligram, and the percentage weight of each organ as compared to the total body weight was determined.

The averages of the percentages of the viscera of the twenty-one male turtles, for there was but one female in the lot, are as follows: heart, 0.32 per cent; spleen, 0.22 per cent; lungs and trachea, 1.07 per cent; digestive tract without contents, 6.23 per cent; liver, 5.43 per cent; pancreas, 0.16 per cent; kidney, 0.32 per cent, and the testes, 0.23 per cent.

The coefficient of variability is smallest for the digestive tract and liver, being 8.05 and 9.43, respectively. In an increasing series come the heart with a coefficient of variability of 10.84; the kidneys, 12.44; the pancreas, 23.13; the lungs 27.03, and the spleen which has a coefficient of variability of 33.46. The testes are the most variable, having a coefficient of 35.66.

36. *Secretion antecedents in the cells of the pars intermedia of the hypophysis of the pig.* DEAN DEWITT LEWIS and SIEGFRIED MAURER, Hull Laboratory of Anatomy, University of Chicago. Research aided by a fund contributed by Mrs. Nettie F. McCormick.

Two kinds of epithelial cells occur in the juxta neural portion of the pars intermedia: 1) cells related to the colloid-containing vesicles, and evidently the secretory source of this colloid; 2) the secretory cells which are the characteristic element of the pars intermedia, hitherto

vaguely described as finely granular, basophile, neutrophile, etc. The cells of the second type constitute the conspicuous element of this division of the gland enabling one to demarcate with perfect certainty the limits of the physiological unit, provided the technical handling of the material is adequate to preserve the secretory antecedents in the cells. This material is highly labile and disappears from the cells rapidly after death. These cells are polygonal in shape, much larger than the colloid-producing cells. The nucleus is excentric in position, rather rich in chromatin. Alongside of the nucleus is a mass of cytoplasm about equal in size to the nucleus containing many mitochondrial filaments of minute size, and containing also a small sphere with centrioles. From this point as a center radiate cytoplasmic strands which divide the rest of the cell up into compartments, each of which is filled with the antecedent to the secretion. The cells around the colloid vesicles are small clear epithelial cells tending to a cylindrical shape, which, however, is much modified by the intrusion into their layer of cells of type 2. At the free margins of these cells the usual terminal bars are seen. These cells are poor in mitochondria, and contain, though rarely, small masses of colloid similar to that in the vesicle. Their activity apparently is low and intermittent.

37. *The rapid formation of vacuoles due to the presence of Bacillus typhosus in the cells of tissue cultures.* MARGARET REED LEWIS, Department of Embryology, Carnegie Institution of Washington.

When certain strains of *Bacillus typhosus* were introduced into the tissue cultures of the intestine of a chick embryo, vacuoles appeared in the cytoplasm of the cells within a very short while. These rapidly increased in number and size so that after a few hours the cytoplasm became crowded with the bodies. The cultures containing the bacteria usually died within twenty-four hours, although the normal cultures lived for eight or ten days. The vacuoles stain red with neutral red. Occasionally one or more bacilli were observed within a vacuole. These organisms were not killed by the cell, but continued to exhibit great motility, dashing about the limits of the vacuole. When the preparation was stained with neutral red, the vacuoles became red, but the bacilli remained unstained although they became less active.

Each of the three types of cells (connective-tissue, endodermal, and mesothelial) became vacuolated, and a few cells of each of these tissues contained bacilli in certain of the vacuoles.

The vacuoles were arranged around an area which seemed to be the centrosphere at one side of the nucleus. Within this non-vacuolated cytoplasm was the typical dumb-bell-shaped or double centriole. This arrangement of vacuoles was the same as that described by Lewis ('19) in the cells of old cultures under usual conditions.

38. *The action of potassium permanganate on the mesenchyme cells in tissue cultures.* WARREN H. LEWIS, Department of Embryology, Carnegie Institution of Washington.

Cultures treated with a few drops of the potassium-permanganate solution of strengths varying from 1 to 20,000 to 1 to 80,000 are usually killed in from three to thirty minutes. An interesting series of reactions takes place in the dying cell. The nucleus is usually first affected, it becomes mottled, more refractive, a membrane appears, and finally clear vacuoles are given off with a corresponding shrinkage in size, resulting in pycnotic nuclei which stain deeply in fixed material.

Shortly after the nuclear changes begin, the mitochondria become more or less irregular, often break up into shorter lengths and later swell up into vesicles—the long mitochondria form large vesicles, the short ones smaller ones. Mitochondria stained with janus black lose color.

Cells fixed while these changes are going on often show important alterations in the cytoplasm. The endoplasm seems to become more or less concentrated into a dense, deeply staining mass sometimes on the same side of the nucleus with the centrosphere sometimes on the opposite side. The centrosphere does not appear to be affected. As the cell dies, the granules and vacuoles, which normally take up neutral red, will, if already stained with this dye, lose their color.

The nuclear changes remind one of the separation out of the chromosomes and nuclear sap in mitosis. In each there is a segregation of nuclear material.

Mitochondria are supposed to consist of phospholipins—oxidations of phospholipins increases their affinity for water—hence the swelling of the mitochondria.

39. *A case of polydactyly in a 22-mm. embryo.* P. E. LINEBACK, Atlanta Medical School.

In the laboratory of the author there is a 22-mm. embryo with a supernumerary digit on the right thumb. As far as is generally known, this is the youngest case of polydactyly on record, and to this fact is attached the chief interest. The majority of such cases come to notice usually at birth or are found in abortions of late pregnancy.

Investigation of these cases has been conducted mainly by anthropologists, and some interesting data concerning inheritance in this class of phenomena have been furnished by them. According to Stieve, there are no recorded cases of unilateral hyperphalangiae of the thumb with such a family history. He cites thirty-nine cases of bilateral hyperphalangiae and only sixteen cases of unilateral, and accounts for this discrepancy on the ground of failure to observe many cases of the latter because of the absence of this family record.

To the anatomist the main interest in these cases of hyperphalangiae of the thumb lies in the material offered for the investigation of the diphalangial condition of the thumb. The present case, because of its age, would seem to offer valuable data concerning the early changes in

cells, and tissue differentiation to form the distinctive structure of the thumb. At the present state of the investigation, however, nothing of value may be offered to this end.

40. *The oestrus cycle in the rat.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

(Abstracts of a monographic account of the physiology of reproduction in the rat to be published at an early date.)

Observations on the living animal. During the last three years a great many observations on several hundred healthy young adult rats have established the existence of a typical oestrous cycle for this animal. Five stages may be distinguished in this cycle by means of characteristic changes in the cellular- and fluid-content of the vagina, changes which stand in a definite relation with alterations in the external appearance of the genitals and with equally definite changes in the uterus and ovary.

The normal length of this cycle lies between four and five days. About one-half of the time occupied by the cycle is represented by the so-called quiescent stage or pause (the dioestrous interval of Heape) or stage 4 of our notation, and the remaining half of the cycle is involved in the more active changes associated with the phenomena of oestrus and ovulation, which have been designated as stages 0, 1, 2, and 3, respectively. These four stages might appropriately be designated as the preparation for oestrus, the period of oestrus proper, the period of ovulation, and the period of epithelial tissue destruction accompanied by leucocytic infiltration.

From the statement above concerning the time occupied by the dioestrous interval it is evident that about half of all animals examined at any one time will be found in this quiescent stage. At any time during this phase of the cycle the vaginal mucosa as examined with the speculum is pinkish, moist, and glistening, and the vaginal content, removed by spatula or other appropriate instrument, consists of a variable quantity of thin, somewhat stringy mucus with which are entangled variable numbers of leucocytes and epithelial cells.

Stage 0, which we have termed the preparation for oestrus (Heape's pro-oestrus), is characterized by a sudden change in the vaginal smear, from which almost all of the fluid and all of the leucocytes have now disappeared, the smear consisting exclusively of great numbers of epithelial cells of strikingly uniform size occurring singly or in sheets. Associated with this change in the smear, which we have adopted as a criterion of stage 0, are equally marked changes in the gross appearance of the vaginal mucosa, for the latter has become somewhat drier and less glistening. In some animals a further external characteristic of the stage may be found in an increasing turgescence of the radiating folds about the vaginal aperture. The average duration of the stage is twelve hours. Toward the end of it a certain portion of females will copulate.

Stage 1 is characterized by an equally definite change in the vaginal smear for the nucleated epithelial cells characteristic of stage 0 are rather suddenly replaced by cornified cells, large, transparent, non-nucleated, scale-like elements which during this stage do not accumulate in macroscopic amounts. The smear still remains free from leucocytes, which had been present during the dioestrous interval and whose sudden disappearance was so marked a characteristic of the preceding stage. The speculum discloses a vaginal mucosa at this stage much less translucent than usual, whitish in color, lusterless, and dry. The turgescence of the vaginal opening which has been noted in the preceding stage may continue or be evident for the first time. All of the normal animals tested by us at this stage manifest oestrous excitement and will copulate.

Stage 2, which cannot be separated abruptly from stage 1, nevertheless differs from it in two marked particulars, first, in the accumulation of such considerable quantities of cornified cells as to form easily visible masses of whitish, granular substance within the cavity of the vagina and, secondly, in the fact that animals in this stage will no longer accept coitus. The vaginal smear shows that the white, granular masses consist exclusively of enormous numbers of cornified cells without the addition of leucocytes or other elements. The average length of stages 1 and 2 is twenty-seven hours.

Stage 3 is inaugurated by the appearance in the vaginal smear of leucocytes among the cornified cells and ends with the disappearance of the latter. The leucocytes cause a softening of the granular masses of the latter to a cheesy, creamy, and increasingly fluid consistency. Before the cornified cells have completely vanished epithelial cells reappear, so that during a short interval all three cellular types are present (cornified, noncornified, and leucocytes). This ushers in the beginning of the dioestrous pause, which may be recognized by the disappearance of cornified elements and the domination of the smear by leucocytes and epithelial cells. Stage 3 is normally of about six hours' duration.

Correlated conditions found in sections of vagina, uterus, oviduct, and ovary. Histological changes in every portion of the reproductive tract are correlated with the above stages which we have characterized by means of the vaginal smear.

During the dioestrous interval the vaginal mucosa is thin (four to seven cell layers) and the squamous transformation of its upper cells only slight. It remains infiltrated by leucocytes and constantly decreases in thickness through dehiscence of its superficial cells, a process evidently not completely compensated for by mitosis in the basal layer. Near the end of the 'interval' the epithelium becomes somewhat thicker (eight to nine cells), the squamous transformation more marked, and the surface cells swollen in a characteristic way to become a well-defined layer (the layer of '0 cells'). The uterus during the dioestrous interval is always slender and with a slit-like lumen; eggs

from the preceding ovulation may be recognized in the proximal portion of the oviduct, even in the middle of the interval. The ovary contains moderately large follicles and well-developed corpora.

The stage preparatory to oestrus, which we have designated as stage 0, shows the vaginal epithelium now having attained its greatest height (nine to twelve cells) and the development of a cornified layer and stratum granulosum under the superficial layer of swollen epithelial cells which, when detached, constitutes the cells of the vaginal smear typical of this stage.¹ Leucocytic migration into the epithelial has ceased. The uterus, which is hyperaemic toward the end of stage 0, becomes distended with fluid, its epithelium changing thereby from columnar to cuboidal. The fluid probably serves as a medium through which spermatozoa may swim rapidly toward the oviduct since spermatozoa from the vasa deferentia when added to such fluid become very active. The ovary shows a continued growth of follicles.

Stage 1, characterized by a vaginal smear in which cornified cells have replaced the epithelial elements of stage 0, shows a vaginal mucosa in which the stratum cornium is now superficial. The latter aided by the general height of the epithelium doubtless causes the dry and lusterless appearance of the mucosa in the gross, and by gradual dehiscence furnishes the cells of the smear. The epithelium is still free from leucocytes. The uterus exhibits its most marked vascular congestion and reaches its greatest distention in the early part of this stage. The distention disappears about the end of the stage, when a columnar epithelium succeeds the cuboidal type found at the time of maximum diameter. The phenomena of hyperaemia and the distention of the uterus beginning in the latter part of stage 0 and reaching their culmination in the first part of stage 1 correspond accurately with the period of maximum exhibition of oestrus. During stage 1 the ovarian follicles reach their maximum size, and toward the end of it the first maturation division may be detected.

Stage 2 is characterized by a continued reduction of the vaginal epithelium (five to nine cells), by the complete detachment of the stratum cornium, and the disappearance of the usual, thin, subjacent stratum granulosum. It will be remembered that this is the stage of accumulation of considerable granular masses in the vaginal lumen. Leucocytes have not yet entered the epithelium in any numbers. The epithelium of the uterus at stage 2 begins to undergo a degeneration characterized by the enlargement of 'vacuolar' cavities. Stage 2 is further typified by the occurrence of ovulation.

¹ The appearance of the cornified layer actually beneath the surface of the epithelium is a remarkable histogenetic process noted long ago, but not accurately described, by Retterer and apparently lost sight of entirely by subsequent investigators. The French observer recognized the process in several forms. Subsequently to the above observations, we have been able to satisfy ourselves of its occurrence in the guinea-pig, and Corner and Pelkan in the rabbit. It constitutes one of the few omissions in the model papers on oestrus in the guinea-pig by Stockard and Papanicolaou whose work marks so significant a step in our knowledge of this subject.

In stage 3, the smear of which is characterized by cornified cells admixed with leucocytes, the vaginal epithelium becomes progressively lower (four to eight cells), and through complete dehiscence no vestige of the stratum cornium or granulosum can be found, unless it be in isolated patches in the vagina. An extensive leucocytic infiltration of the vaginal epithelium is now manifested. The uterine epithelium is still undergoing its 'vacuolar' degeneration and leucocytic infiltration may also be detected there. Eggs are normally encountered traversing the oviduct, while the ovary is characterized by the vigorous growth of the newly formed corpora lutea.

Length of the cycle. About two thousand cycles have been observed in some three hundred animals, many of which were observed for as many as twenty consecutive cycles. As may be seen by the accompanying table, by far the most of the cases (82 per cent) are of oestrus cycles four, five, and six days in length. Records of the succession of cycles in individual rats show such considerable variations that it may be said that only about 50 per cent of all animals have cycles which may be depended upon to vary by less than two days in length. Even in the latter group, some individuals exhibit curious instances of a longer cycle interpolated in a long series of regular cycles of normal duration. One may also point out that a small proportion of all perfectly normal individuals exhibit such irregularity in their cycles as to be unavailable for experimental work.

Table of observed instances of oestrus cycles of various lengths

LENGTH OF CYCLE IN DAYS	NUMBER OF INSTANCES	
3	65	}82% Average 4.6 days
4	789	
5	634	
6	233	}92% Average 4.8 days
7	69	
8	60	
8	30	
10	24	
11	16	
12	22	
13 and over	57	
		1999..... General average 5.4 days

41. *On the attainment of sexual maturity and the character of the first oestrus cycle in the rat.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

Careful observations have been carried out on considerably more than two hundred animals from the time of weaning until the attainment of sexual maturity. While these data are insufficient for statistical purposes, they nevertheless demonstrate clearly the great variation in the time of onset of puberty which may be attained as early as the forty-fifth or delayed until the one hundred and twentieth day.

Similarly, sisters of the same litter show a great variation, though seldom of this maximum extent. These facts would appear of much importance in the light of reputed influence on sexual maturity of various experimental procedures, especially endocrine therapy (vida Goetsch, '16). The data, which will be greatly enlarged, indicate that about 16 per cent of all individuals are mature by the sixtieth day of age, 30 per cent about the seventieth, somewhat over 60 per cent by the eightieth, somewhat over 80 per cent by the ninetieth, and fully 95 per cent by the one hundredth day. They indicate further that in spite of the existence of this variation more than half of all cases would appear to mature in the interval between the seventieth and ninetieth days. We have defined maturity as the opening of the vaginal orifice. The thin epithelial membrane which forms at the site of the future introitus and which is not without resemblance to a cicatrix ruptures spontaneously. The first ovulation is coincident with this event, as sections of the ovaries and oviduct demonstrate. In many cases the vaginal smear shows at the time of opening stages 0 to 2, so that a typical oestrus is present. The rupture of the vaginal membrane may take place in two areas, leaving a vertical median cord which may persist throughout the first gestation.

Many observations show that the first two or three oestrus cycles which succeed the initial one are usually longer than those which occur later.

42. Effect on the oestrus cycle of the removal of various portions of the reproductive system. JOSEPH A. LONG and HERBERT M. EVANS, University of California.

Removal of the entire uterus including the cervix does not influence the regular recurrence of oestrus other than through an initial delay which occurs in some cases, doubtless as a result of the shock of the operation. Double ovariectomy causes a complete cessation of oestrus, although the excision of the ovaries just preceding an expected oestrus may not influence the occurrence of that particular oestrus.

43. Rhythmical recurrence of the typical oestrus cycle after ovarian transplantation. JOSEPH A. LONG and HERBERT M. EVANS, University of California.

Fourteen instances of successful transplantation of the ovaries into the spleen, mesometrium, and rectus muscle have been secured and the oestrus cycles of these followed for somewhat over four months after the operation. Recognition of the vaginal changes associated with oestrus furnishes a positive method for the detection of the surgical success of the transplant and proof of the continued physiological function of the same. In most successful cases, the first interval after the operation was only slightly longer than the dioestrous interval of normal cycles. Sections show that such transplanted ovaries are essentially normal in containing healthy and atretic follicles, corpora lutea of several ages, and interstitial tissue. They demonstrate that in the

absence of any true ovulation there is nevertheless an apparent rhythmic production of corpora lutea from unburst follicles as is known to occur rarely in normal animals.

44. *The effect of copulation in delaying the occurrence of the next oestrus cycle and the production of a similar effect by mechanical stimulation of the cervix.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

When normal females of the rat are permitted to copulate with vasectomized males some of the effects of coitus other than conception may be secured. The 'plug' (which, as Walker has shown, is the result of the secretion of the prostate and a special gland, the coagulating gland), although free from sperm, is nevertheless ejaculated by such males and fills the vaginal lumen. Females which have been mated in this way, although not becoming pregnant, usually show a delay of from four to ten days in the appearance of the next oestrus. A similar effect may be secured when normal males are mated with females suffering from complete stricture of the oviducts. It was thought possible that this delay in the oestrus might be due to some portion of the prostatic secretion, and this substance was consequently injected into the uterus through the cervical canal. The injection of Ringer's solution in the same way was, however, found to give the same effect. Finally, the correct explanation was discovered in the irritation of the cervix itself which the glass cannulae had caused, for the simple introduction of a small glass rod gives an identical response. Not more than 1 mm. of the cervical canal need be traversed in order to secure the effect. It is hence altogether likely that the simulation of the effect of copulation by mechanical stimulation is due to the fact that the hard vaginal plug impinges upon and protrudes slightly into the cervical canal. The effect may be produced with equal ease after hysterectomy and in animals in which the mammary glands have been completely excised shortly after birth. The effect may similarly be produced after double ovariectomy, providing normal oestrus cycles have secondarily been secured by successful transplantation of the ovaries. It would appear unlikely that this may be explained on the basis of any reflex nervous effect on the ovary itself. Stimulation of the uterine mucosa by an aperture in its peritoneal surface rather than through the cervix, has not shown such an effect. The effect is consequently peculiar to the cervical mucosa, most of which is lined by a typical stratified, squamous epithelium. It is produced with greatest reliability during stages 0, 1, and 2 of the oestrus cycle. The delay in the appearance of oestrus is correlated with a similar delay in ovulation, as has been established by the administration of vital dye to mark all corpora lutea present at the time of cervical stimulation. It would not appear improbable that this delay is a contrivance to ensure implantation. The time relations involved are significant. In the rat four days occur between copulation and the arrival of segmenting ova in the uterus. According to our work, a new cycle would be under way at that time if oestrus had not been delayed in this way by the effect of copulation. Furthermore, experi-

mental deciduomata undergo complete regression with the onset of the next oestrus, and it is consequently possible that could oestrus occur it would prevent implantation.

45. *The inhibition of oestrus and ovulation by lactation.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

Young rats may usually be weaned after twenty-one days of suckling, but if left with the mother the duration of lactation may be almost double this time. Daily microscopic examinations of the vaginal smear from suckling mothers show the persistence of the condition characterizing the dioestrous interval. Typical oestrous changes recur in from three to twelve days after the removal of the young and will occur spontaneously before the end of greatly prolonged periods of nursing.

Proof that ovulation does not occur during this period is furnished by use of vital dye administered during pregnancy in order to mark the corpora of gestation. If animals are now killed during lactation, only a single unstained set of corpora are found, the corpora of lactation. On the incidence of an oestrus cycle after the removal of the young, the first other corpora to be found now add themselves to those already present. Instances of pregnancy occurring early in lactation are due to fruitful copulation on the day of littering, and in such instances the same corpora function simultaneously as those of lactation and of the second pregnancy.

46. *Corpora lutea of lactation in the rat as distinguished from the corpora of pregnancy and those of ovulation.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

Certain vital dyes administered during the last week of pregnancy are deposited in the cells of the only corpora lutea then present (corpora lutea gravidatis). We have experimented with somewhat over seventy substances of known chemical constitution and found but two suited for such a purpose, the benzidine dye formed by the combination of dichlorbenzidine with two molecules of 1.8 aminonaphthol 3.6 disulphonic acid, and that formed by combining orthotolidine with a molecule each of the Neville-Winther acid and of chromatropic acid. Toxicity of the first dyestuff renders it unreliable for work in which we must be certain to preserve normal physiological conditions, but the second vital color is not open to this objection. The dye persists in the corpora up to the time of their disappearance and consequently serves as a means of identification of them, for corpora arising subsequently to dye treatment are not stained.

In the ovaries of rats treated in this manner and killed, for example, at the end of the first week of lactation two kinds of corpora lutea may be recognized, those possessing dye deposits and those which are uncolored. The latter are consequently recent structures and must all result from the ovulation well known to occur within twenty-four hours after littering. They may appropriately be termed corpora lutea of lactation and differ in size and structure from both of the other types of corpora. These corpora are intermediate in size between the corpora of pregnancy and those of ovulation. It is interesting that even in cases

of prolonged lactation, where they may be considered as functioning longer than do the corpora of gestation, they do not attain the greatest size reached by the latter. Structurally, a pronounced difference from other corpora is found in the characteristic picture of uniformly distributed, very small lipoid granules possessed by the lactation lutein cells. Although the process of suckling thus produces characteristic changes in corpora lutea, the latter structures and, indeed, the ovary itself are unnecessary for the further performance of lactation.

47. *The survival and time of disappearance of the corpora lutea of pregnancy in the rat under various conditions.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

If the corpora lutea of pregnancy are dyed vitally during the last week of gestation, they may be recognized subsequently as long as they persist in the ovary. With advancing age the lutein cells lose their deposits of vital dye and become fewer in number until their disappearance. The vital dye, however, remains within the confines of the corpus, having been taken up by macrophages which assemble at the beginning of degeneration and become gorged with color.

Under the simplest conditions, i.e., when the animal neither suckles nor becomes pregnant again, vestiges of these corpora of gestation may be detected with the naked eye as small blue spots as late as more than one hundred days postpartum. Under these conditions the ovary comes to contain a large number of small corpora lutea of ovulation formed, as we now know, at intervals of from four to five days. The first set of these corpora is formed from the ovulation which invariably occurs within twenty-four hours after littering. If the animal is allowed to suckle her young or to become pregnant again, the corpora of this ovulation become transformed into corpora of lactation or pregnancy. In the presence of the latter structures which grow rapidly the corpora of the preceding pregnancy degenerate much earlier.

48. *The experimental production of deciduomata in the rat, with special reference to the phases of the oestrus cycle.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

The possibility of the experimental production of deciduomata discovered by Leo Loeb working with the guinea-pig and confirmed by Frank and by Corner and Warren in the rat can now be studied in its relation to phases of the oestrus cycle. Such a correlation is necessary in order to inquire into the validity of the theory of the participation of young corpora lutea in the phenomenon of implantation by their supposed secretion of a hormone which sensitizes the uterine mucosa.

Deciduomata of appreciable size are difficult to produce during the normal short oestrus cycle which characterizes the rat, but may reach a larger size if the uterine operation is carried out from four to six days after a mechanical stimulation of the cervix. As has been shown separately, such a stimulation produces the same effect in delaying the appearance of the next oestrus cycle as does copulation. The fact that the uterine growths are most pronounced when the operation is carried out within this time interval (the cervical stimulation always being per-

formed at stages 0 or 1 of the normal oestrus cycle) would appear significant in the light of our knowledge that normal implantation occurs at this time. Such large deciduomata undergo complete regression and absorption on the incidence of the next oestrus, a sufficient explanation of the difficulty of producing deciduomata unless the cycle is artificially prolonged. However, the inhibition of oestrus by lactation is not favorable for deciduomata formation, and it would appear from this that the uterine mucosa during nursing is not in the same condition as it is succeeding coitus. The deciduomata reaction cannot be induced in the presence of a pregnancy. The retention of the foreign body (silk thread, etc.) in the uterus does not produce a second deciduomatous response after the resorption of the first.

49. *A characteristic sign of pregnancy in the rat detectable from the thirteenth to the sixteenth day.* JOSEPH A. LONG and HERBERT M. EVANS, University of California.

Although inspection of the uterus by means of laparotomy will disclose enlargement at the implantation sites as early as the seventh day of gestation, external signs of conception are not evident until considerably later. An increase in size is apparent about the eighteenth day and a presumptive diagnosis may be made somewhat earlier by successive increases in weight. Daily vaginal examinations with the speculum make it possible to detect pregnancy as early as the thirteenth day by the presence of a bright red coloration on the ventral wall of the vagina and near the cervix. The sign appears abruptly and persists until the sixteenth day, the reddish color changing to brown. The vaginal smear displays considerable numbers of free red corpuscles which are never present here during any phases of the normal oestrous cycle or at any other time in the rat.

50. *The growth of embryonic chick liver in tissue cultures.* RUTH S. LYNCH (introduced by W. H. Lewis), Carnegie Laboratory of Embryology.

Small pieces of the liver from embryos, five to fourteen days, were explanted in the usual manner in Locke-Lewis solution. Liver cells begin to migrate out from the explant in the form of a sheet or membrane in from five to forty-eight hours. The maximum outgrowth is usually reached at forty-eight hours. Explants from eight-day embryos gave the best growths. The largest membrane was 27μ wide. The liver cells do not migrate out as readily as do the endodermal cells from the intestine. No mitotic figures were seen.

The flattened cells are crowded with mitochondria (rods, granules, pear-shaped or spherical in form). They vary greatly in size and shape even in the same cells. The largest mitochondria are more peripheral. Rarely are thread-like mitochondria seen. They bend, change shape, move about, and stain with janus green.

Cells from embryos of eight days' incubation or more usually have many fat globules of varying sizes. Cells from five-day embryos have little or no fat.

Degenerative changes usually appear in about seventy-two hours. The cytoplasm gradually becomes filled with vacuoles which increase in size and number. The vacuoles contain small granules in Brownian motion. The granules stain more deeply with neutral red than the fluid contents of the vacuoles. Free granules in the cytoplasm, which take up the neutral red, seem to be rather rare. The degenerating cells do not show centrospheres as do the mesenchyme cells, and the centriole was not located.

51. *A study of the dorsal vagus nucleus in mammals.* EDWARD F. MALONE, University of Cincinnati.

In 1910 Molhant demonstrated that the dorsal vagus nucleus gives origin to all the fibers of the vagus which supply smooth muscle and heart muscle, and that no other fibers arise from the cells of this nucleus. He also showed that the two ends of this cell column innervate smooth muscle, while the middle portion supplies heart muscle. An exceptional opportunity was thus offered to study the cells which innervate these two types of muscle. In 1913 I described in the lemur and monkey two types of cells in this nucleus. The two ends of the cell column are composed of small cells, while the middle (which supplies the heart) consists of large cells which are intermediate in character between those which supply smooth muscle and skeletal muscle.

Since 1913 this study has been extended so that it includes the following animals: rabbit, cat, lemur, monkey, and man. In all animals the same two types of cells were found, and their exact distribution has been recorded in numerous drawings of sections of each of these animals. This distribution is similar in all, but in some the segregation of each cell type into a distinct cell group is striking, while in other animals the two cell groups overlap to a greater extent, and at this point of contact the two types of cells are intermingled. This difficulty made it impossible without systematic study to recognize within the dorsal vagus nucleus two types of cells with constant distribution.

52. *Similarities between the lateral-line organs of elasmobranchs and those of amphibians.* H. W. NORRIS, Grinnell College.

Naked neuromasts in amphibians correspond to pit-organs and canal-organs in the elasmobranch fishes. Supraorbital and infraorbital groups are found in each. The mandibular series of neuromasts of amphibians is distinctly double, oral, and gular. Similarly in elasmobranchs the mandibular and hyomandibular canal organs correspond to the oral series and a mandibular row of pit-organs to the gular series of neuromasts of amphibians. The innervating nerves of the amphibian oral and gular neuromasts, rami mentales externus and internus, have their corresponding rami in the two main branches of the ramus mandibularis externus of elasmobranchs. The vaguely defined occipital group of neuromasts of amphibians, innervated by the rami supratemporalis and auricularis vagi, corresponds to the sense-organs of the supratemporal canal (together with other canal organs and pit-organs

in the immediate vicinity) innervated by the rami supratemporalis glossopharyngei and supratemporalis vagi of elasmobranchs. Three lines of neuromasts occur on the trunk of the body in amphibians, innervated by three distinct nerve rami. Three series of lateral-line organs are to be found on the trunk in elasmobranchs: a dorsal line of pit-organs innervated by a ramus dorsalis vagi, a middle series of canal and pit-organs innervated by the main lateral-line nerve, and a ventral series of pit-organs innervated by a branch of the fourth branchial nerve. In amphibians the ventral series is supplied by a branch of the ramus recurrens vagi, a supposed derivative of one or more primitive branchial nerves.

53. *Influence of removal of corpora lutea and ripe follicles on the oestrous periodicity in guinea-pigs.* GEORGE N. PAPANICOLAOU, Cornell University Medical College.

A number of operations were performed on guinea-pigs to ascertain the influence of the removal of the corpora lutea on the oestrous cycle in non-mated animals.

Removal of the corpora lutea within twenty-four hours after oestrus and ovulation accelerated the appearance of the next ovulation and oestrus, the interval being reduced to about eleven days, instead of the usual sixteen to seventeen days.

Similar operations performed four, eight, and twelve days after oestrus also reduced the resting interval, the next ovulation and oestrus occurring respectively thirteen, fourteen, and fifteen days after the previous oestrus.

These operations show that the removal of the corpora lutea has a decided influence on the oestrous cycle, producing a definite reduction in the length of the dioestrus. Expressed directly, the presence of the corpora lutea maintains or prolongs the interval of time between two ovulations or oestra.

Control operations of removal of part of ovaries, without injuring the existing corpora lutea, have shown such a removal, if not extensive, to be ineffective in altering the oestrous cycle. Extensive lesions of the ovaries, on the other hand, may induce a defective function and thus a retardation of the process of growth and ripening of new follicles and thus a late appearance of the next ovulation and oestrus.

The removal of the ripe follicles a few hours before ovulation, results in a retardation of one or two days in the appearance of the next ovulation and oestrus. This retardation of one or two days corresponds to the time needed in order that other large follicles may grow to the point of development that had been attained by the removed follicles.

All of these operations were performed in semi-spayed females, possessing only one ovary, the operation being thus easier and more exact. Animals with only one ovary have a very regular oestrous cycle, the only peculiarity being that the oestrous cycle in such animals is about one day longer than in those possessing both ovaries.

54. *Heart, musculature of atria.* JAMES W. PAPEZ, Emory University.

It is the purpose of this work to show the muscular bundles of the atria. Most of them arise in the septum. The interauricular band and outer bundles of the right auricle arise in the sino-auricular node.

Right auricle: The interauricular band arises from the node and extends to the left appendage. The external bundles arise from the node and spread over the auricle. The anterior crest arises from the septum and gives origin to the anterior pectinate muscles. The posterior crest arises from the septum and gives origin to the posterior pectinate muscles.

Sinus venosus: The intercaval bundle arises from the septum and spreads over the right auricle. The superior vena caval bundles arise from the node and septum and encircle the vena cava. The right leaf of the septum secundum arises from the septum and spreads over the interior vena cava. The right leaf of the septum primum arises in the septum and passes in the valve of the inferior vena cava.

Left atrium: The anterior crest comes from the septum and interauricular band. The posterior crest comes from the band and septum. The septopulmonary bundle arises from the septum and covers the roof of the atrium. The left leaf of the septum secundum arises from the septum and spreads over the back of the atrium. The septoatrial bundle arises in the septum and spreads through the roof of the atrium. The left leaf of the septum primum arises from the septum and passes around the base of the atrium.

55. *On the development of the tâches laiteuses in the omentum of the rabbit and the relation of the macrophages to the fixed tissue.* EMILY H. PAYNE (introduced by Hal Downey), University of Minnesota.

Numerous tâches laiteuses are developing in five to twelve-day-old rabbits. The majority of these develop in connection with blood-vessels. Others arise later during the retrogression and degeneration of this primary capillary network. Both types of tâches laiteuses originate as local differentiations of the fixed tissue. These differentiations consist of, 1) a proliferation of the fibroblasts and a subsequent liberation of the daughter cells to form free mononuclear wandering cells, and, 2) the addition of perithelial cells from the walls of adjacent vessels. Tâches laiteuses developing in the neighborhood of degenerating vessels are enlarged by the direct survival of healthy endothelial cells which have become separated from the core of the degenerating vessel. The endothelial and perithelial cells thus liberated may divide and so change their character as to become indistinguishable from the other cells of the tâches laiteuses.

The endothelial cells, then, are not specifically differentiated cells incapable of further change. The perithelial cells do not represent the persistence of an embryonic type of cell (Marchand): many of them are derived from perivascular fibroblasts.

Developing tâches laiteuses are composed almost wholly of large free and partially free mononuclear cells. As the tâches laiteuses increase

in size there is a gradual differentiation of the inner cells to form, 1) smaller macrophages, 2) typical lymphocytes, 3) plasma cells. The fibroblasts at the periphery of the tâches laiteuses continue to proliferate and to separate from the surrounding tissue. These cells are of the typical macrophage type and have a greater affinity for colloidal dyes than the fixed cells from which they arise.

In the omentum, as in other lymphoid organs, the fixed tissue cell is thus the mother cell of various types of lymphoid wandering cells. While in the fixed condition, cells usually have only a slight affinity for the 'vital dyes.' When these cells become partially free, for instance at the periphery of the tâches laiteuses and the sinuses of lymph nodes, their power of phagocytosis is greatly increased. Large mononuclear cells recently liberated from the fixed tissue have a still greater ability to phagocytose foreign matter, and these cells may become loaded with dye. With repeated division and further differentiation, these large cells gradually lose their phagocytic function and other macrophage characteristics. They become morphologically identical with the typical lymphocytes of other lymphoid organs and like them may further differentiate into plasma cells and granulocytes.

The usual connection of the developing lymphoid patches with blood-vessels, and the gradual dying out of these in older animals after the retrogression of the blood vessels, suggests that a definite blood supply is favorable to the development and existence of the tâches laiteuses, and that the absence of vessels is followed by a disappearance of the patch. In the adult, new tâches laiteuses may be formed in essentially the same manner as in the young animal. But here the process of differentiation is greatly speeded up, and the tâche laiteuse is maintained chiefly by homoplastic regeneration of its free cells.

56. *The problem of middle-ear mechanics and its relation to sound transmission and sound analysis.* A. G. POHLMAN, Saint Louis University.

There are two chief objections to the usual theories of sound transmission and analysis: first, because of a misconception of the character and behavior of sound vibrations, and, second, because of the misinterpretation of the middle-ear complex in its relation to sound transmission. The commonly accepted 'bent-lever' theory of von Helmholtz results in perilymphatic displacement and is applied directly to the 'resonator theory' or to the modifications of the 'telephone theory' through the membrana basilaris or membrana tectoria, or to the recent Wrightson theory of a cochlear 'hydraulic weighing-engine.' The writer desires to present the evidence for the molecular nature of sound propagation; the reactions of the drum membrane to molecular and molar displacement factors; the adjustability of the sound-transmission system in anurans, birds, and mammals; the functional interpretation of the intrinsic ear musculature in these forms and their relation to the passive traction system of elastic ligaments; the relation of the closed tuba auditiva to the intratympanic pressure; the regulation of perilymphatic pressure and the phylogenesis of the membrana tympani

secundaria; the registration of molecular sound vibrations as opposed to the various displacement theories; the bone conduction of sound; the establishment of an hypothesis for a middle-ear function and an inner-ear function which will hold for all higher vertebrates.

The writer believes the topic is important and that it is fundamental to the correlation of structure and function. Time has therefore been requested for a proper presentation of this paper to any who are interested that the problem may be freely discussed.

57. *The effects of cold and low oxygen atmosphere on the developing chick.*

C. W. M. POYNTER, University of Nebraska Medical School.

Chick embryos at different stages of early incubation were refrigerated for varying lengths of time and then incubation continued; also embryos were grown in vacua of different degrees and in atmosphere low in oxygen at normal pressure. The resulting embryos presented a great variety of developmental irregularities, consequently these methods furnish a simple procedure for the study of abnormalities in a warm-blooded animal.

The different types of abnormalities will be reviewed and the effects of treatment at different stages of development will be discussed.

58. *Vacuoles formed in certain cells studied under abnormal conditions.*

ROSA E. PRIGOLEN (introduced by W. H. Lewis), Johns Hopkins Medical School.

Film preparations of the subcutaneous tissue of chick embryos (of eight to ten days' incubation) were studied in Locke-Lewis solution and also in the same solution to which neutral red had been added. Immediately after preparation no vacuoles were to be found in the fibroblasts or in the red blood-cell, but the clasmotocytes contained one or more of these bodies.

After from twenty to thirty minutes vacuoles appeared in the cytoplasm, not only of the fibroblasts, but also of the red blood-cells. These bodies increased in size and also in number up to a certain extent. The opacity of these bodies easily distinguishes them from the other more highly refractive bodies of the cytoplasm, i.e., the fat globules and the mitochondria. When such preparations were stained with neutral red, these bodies became red.

In the neutral-red preparations the vacuoles were red from their initial appearance. The color was slightly orange, and frequently a deeply stained red granule was found within the paler vacuoles.

In the fibroblasts small neutral-red granules and vacuoles of various sizes became located around an area at one side of the nucleus, probably the centrosphere, since it corresponded with that structure described by Lewis ('19).

Observations were also carried out upon human blood. Here it was found that none of the blood-cells contained vacuoles immediately upon withdrawal from the circulation. The leucocytes did, however, develop vacuoles after from twenty to thirty minutes in the above solutions.

59. *The hypophysis cerebri of the American marmot (Marmota monax) with special reference to changes during hibernation.* A. T. RASMUSSEN, Institute of Anatomy, University of Minnesota.

Since far-reaching deductions have been made from limited observations upon the hypophysis during hibernation, further studies seem justified.

This report is based upon 32 woodchucks sacrificed at different intervals before, during and after winter-sleep. The tissue was fixed *in situ* by injection of different fixers into the vascular system. Serial sections were cut 5μ , with a limited region cut 2μ , and stained by a variety of methods.

The gland as a whole is discoidal in shape. The pars anterior forms a crescent-shaped lobe half encircling the pars nervosa. The pars intermedia comes to the outer surface only at the most dependent point. The infundibulum retained is solid and unassociated with pars buccalis (glandularis). There is a well marked residual lumen.

Pars intermedia consists of cells with abundant cytoplasm, comparatively free from granules except for numerous mitochondria in the form of round granules and very short rods. Cysts and colloid are often found here.

In pars anterior are clearly three types of cells with few intermediate forms. The chromophobic are most abundant, the acidophilic come next and the basophilic are least numerous. All types contain mitochondria of the same form directly proportional to the amount of cytoplasm. The tendency for the acidophiles to lie next to the blood spaces is conspicuous.

The marked changes reported to take place during hibernation are not apparent. The most constant and striking alteration occurs after waking up when the basophiles become very prominent and show large vacuoles and a conspicuous 'macula.'

60. *On the origin of the eosinophil leucocytes of mammals.* ADOLPH R. RINGOEN, Hematological Laboratory, University of Minnesota.

Researches in this laboratory (Downey, '13, '15, and Ringoen, '15) have proved that Weidenreich's claim with reference to the hemoglobinous origin of the eosinophil leucocyte granules of mammals is inapplicable to the eosinophils of the marrow. The results of the present study show further, in contradistinction to Weidenreich's studies on the local development of eosinophils in the hemolymph nodes of sheep, and in the tâches laiteuses of rabbit omentum following repeated intraperitoneal injections of foreign erythrocytes, that hemoglobin or its dissociation products is not associated with the formation of eosinophil leucocyte granules.

Nothing was observed in the examination of hemolymph nodes which might even suggest that eosinophil leucocyte granules are hemoglobin derivatives. All the evidence favors the view that the granules are true endogenous formations of the cells which contain them.

In the experimental animals repeated intraperitoneal injections of hemoglobin, erythrocyte suspensions, or egg-white—given at eight- to twelve-day intervals—resulted in an eosinophilia of the blood-stream and peritoneal cavity. Phagocytosis of free hemoglobin is evident after single injections of this substance, whereas after erythrocyte injections a similar phagocytosis of hemoglobin occurs after the animal has developed specific hemolysins for the foreign cells. The lymphocytes and eosinophils of the serous cavity, as well as the cells of the omentum, are phagocytic for the free hemoglobin which is readily digested or changed into pigment, but never converted into eosinophil leucocyte granules.

The fact that every animal which showed an eosinophilia also manifested the clinical symptoms of anaphylaxis proves that the eosinophilia is a response on the part of the organism to allergic conditions.

61. Some general characters of the postnatal growth of the various organs in man. RICHARD E. SCAMMON, University of Minnesota.

In postnatal life the simple type of growth curve common to all the organs before birth is entirely lost. Graphs of the postnatal growth of the various organs fall into four main categories and several minor ones. The four main types are as follows:

Type 1. Characteristic of the growth of the total body weight, standing height, and a number of other lineal measurements; and of many of the organs (spleen, heart, liver, pancreas, lungs, kidneys, stomach, intestinal tract, salivary glands, thyroid gland). These graphs show a rapid initial rise in infancy, a period of lessened increase in the middle part of childhood, a prepubertal increase, and an adolescent period of decreased growth.

Type 2. Characteristic of head circumferences, diameters, and volumes, and of the mass increase of the brain, eyeballs, spinal cord, lachrymal gland (?), and meninges. These curves show a rapid increase in infancy and the first period of childhood and a very slow increase thereafter with possibly a slight rise at puberty.

Type 3. Characteristic of the thymus, certain groups of lymph nodes (and probably of most other lymphoid masses). Curves of this type show rapid growth in infancy and childhood, the attainment of greatest mass at puberty and a decline in adolescence and early maturity.

Type 4. Characteristic of the genital organs (with the exception of the uterus and ovaries). These curves show a slow growth in infancy followed by a still slower rate of increase throughout early and middle childhood, and a very rapid increase in the prepubertal period and in adolescence and early maturity. The organs which are known to not conform to the following types are:

a. The hypophysis, which presents a curve of growth intermediate between type 1 (characteristic of most glandular organs) and type 2 (characteristic of nervous tissue). This curve probably represents the complex produced by the growth of the anterior lobe of the hypophysis according to type 1 and the posterior lobe according to type 2.

b. The ovaries, which show a growth curve which approaches that of type 1, but is not identical with it. (The interpretation of this curve is questionable because of the cyclical changes in the ovary.)

c. The suprarenals, which show a great decrease in weight in the neonatal period, an interval from the neonatal period which extends through the greater part of childhood when there is little growth, and period of rather rapid growth in the prepubertal period and in adolescence.

d. The uterus, which shows a curve of growth comparable to that of the genital organs with the exception of a great neonatal decrease and a possible period of limited growth at about six years.

A second grouping of the various organs may be made by determining their total postnatal increase in terms of their natal weight. Organs classified in this way also fall into four main groups and several smaller ones, but these groups are not identical with the types mentioned above.

62. *The postorbital elongation of the skull of the okapi.* H. VON W. SCHULTE, Creighton University.

The Lang-Chapin Expedition of the American Museum of Natural History secured seven skeletons of immature individuals of *Okapia johnsoni*, which have been placed in my hands for study. The following remarks are based on this as yet but partially investigated material.

A character of the adult okapi skull is the lengthening of the post-orbital region due to the elongation of the parietal and supra-occipital bones, in this resembling *Palaeotragus* and differing from the giraffe (*Fraiponi*). In the foetus of 120-mm. length the occiput is already prominent. In a skull of 103-mm. length the postero-lateral fontanelle is larger than that of the giraffe of about the same length figured by Lankester. The supra-occipital of the okapi is prolonged by two elongated interparietal ossicles, which ultimately unite on both sides with the parietals; in the adult skull their identity is lost. The parietal develops a very long postero-inferior angle which closes the fontanelle and reduces the exposed surface of the petrous to a linear strip. Coincidentally with these changes, the basis cranii loses much of its primitive inclination and the cranial vault acquires a nearly horizontal contour. In these characters the giraffe retains more usual proportions; the frontal is, however, sagittally lengthened. These differences seem correlated to the position of the horns which are postorbital in the giraffe, supra-orbital in the okapi and *Palaeotragus*.

In both okapi and giraffe the squamosal is low and elongated; it is overlain on the cranial surface by a thin fenestrated plate of the parietal, the lower edge of which is visible on the basis cranii in the lacerated foramen. This condition is not primitive, indeed is not present until the skull has a length of 145 mm. It appears to be the result of subdural ossification, to which there is a greater tendency in the Giraffidae and Cervidae than among other ungulates (Davidson Black)

63. *On the presence of an additional element in the auditory bulla of the okapi and giraffe.* H. VON W. SCHULTE, Creighton University.

The bulla of the okapi is larger than that of the giraffe, but otherwise very similar. In both I would record the presence of a separate element of doubtful homology which ultimately anchyloses with the tympanic. This is effected in the skull of an okapi 238 mm. in length and in the skull of a giraffe of slightly larger size. After fusion the ossicle forms the most dorsal process of the tympanic. It articulates mesially with the portion of the petrous above the facial canal and its hiatus, both of which it helps to bound. Dorsally it is apposed to the part of the squamosal that encloses the postglenoid canal and anteriorly its edge touches the border of the squamosal behind the glenoid fossa. It is separated from the interior of the cranium by the plate of the parietal which extends to the lacerated foramen. Laterally it is largely covered by the postglenoid process. From the rest of the tympanic it is set off by a deep narrow cleft, at the bottom of which in the larger skulls is a canaliculus opening on the interior of the bulla close to the annulus tympanicus. The fissure corresponds both in form and site to the fissura petrotympanica of other ungulates, and there can be no doubt that the foramen is the iter chordae anterioris. Thus it is evident that the ossicle has the topography of the deflected edge of the tegmen tympani as it appears, for example, in the glenoid fossa of the human skull. It has further the necessary relations to the hiatus and canal of the facial nerve. When it has been stated that by its inner surface it enters into the osseous tube and above it presents a groove such as might lodge the tensor tympani, the evidences have been summarized which might justify its identification with the tegmen tympani or at least its lateral portion. On the other hand, I am not familiar with any observations of the development of the tegmen from a separate center.

64. *On some of the muscles of the shoulder of the okapi.* H. VON W. SCHULTE, Creighton University.

The observations recorded here were made upon a foetal okapi about 120 mm. in length, procured by the Lang-Chapin Expedition of the American Museum of Natural History.

The cephalic and cervical portions of the trapezius are lacking on both sides. The thoracic portion extends at its origin from the first to the eleventh thoracic spine. The insertion is into the spine of the scapula. A sternomastoid and sternomassetericus are present, both well developed. The omotrachelian is very large and is united to the deltoid by a broad inscription. It thus seems to substitute in the brachiocephalicus for the deficiency of the trapezius. Its origin is from the atlas, in which it differs from the giraffe, where it arises from the transverse processes of the sixth and seventh cervical vertebrae (Joly and Lavocat). In another respect the length of the neck of the okapi has proved insufficient to produce modifications; the external branch of the spinal accessory nerve is present with its usual course and termination in the trapezius. This is interesting in view of the absence of

this nerve and its replacement by cervical branches in the camel (Lesbre, Todd), the llama (Lesbre), and the giraffe (Elliot Smith).

65. *Certain features of the anatomy of a 9.5-mm. turtle embryo, especially the transformation of its mesenteric artery.* RALPH F. SHANER, Harvard Medical School, Boston.

The study herewith reported is one of a series conducted in the Harvard Laboratory, designed to show in a readily comparable manner the structure of various vertebrate embryos of a chosen stage of development. The stage desired is that of the well-known 12-mm. pig, but the chick described by Doctor Boyden (*Proc., Anat. Rec.*, 1916, vol. 10, p. 185) and the *Chrysemys picta* now under discussion prove to be somewhat more advanced.

The primary branches of the cerebral nerves, as will be shown in a complete reconstruction, present only slight variations from the mammalian pattern. Most interesting, perhaps, is the segmentation of the ganglion nodosum, previously described by Chiarugi in the snake, but apparently never before figured. In the turtle the upper segment of this ganglion, with branches to the third pharyngeal pouch, is cut off by a deep notch from the lower part, so that it forms really a separate ganglion. The lower segment, subdivisible into two parts, supplies the fourth and fifth pouches.

The venous system as seen in reconstruction is likewise strikingly similar to that of mammals. A large lingua-facial vein has two widely separated outlets and is traveling up the neck as in higher forms. Although the lymphatic system is scarcely indicated at this stage, comparison with older embryos shows that the turtle does not reveal the origin of the lymphatics in the unequivocal manner described by Stromsten. On the contrary, the same difficulties of interpretation are encountered as in mammals.

Before the formation of the primary loop of intestine, a short superior mesenteric artery develops, with a large branch descending along the hind gut. As the primary loop of intestine is formed, the mesenteric artery lengthens, carrying the origin of its branch well out into the loop. The branch then pursues a long recurrent and most disadvantageous course. This is partly corrected by unequal growth and partly by the rotation of the intestine, until finally the recurrent vessel becomes one of a fan of terminal branches, the history of which has not been suspected.

66. *Hermaphroditism in man.* HUBERT SHEPPARD (introduced by G. E. Coghill), University of Kansas.

In 1911 Gudernatsch asserted that "hermaphroditism in the sense that separate testicles and ovaries are found has not been demonstrated in man, nor even in other mammals beyond a doubt." In so far as we are able to determine, this assertion has not been questioned. We thought it worth while, in the light of this and other investigations, to report a study of the anatomical structures of an extreme case of hermaphroditism which came to the dissecting room.

The testicles in this individual were located in the scrotum and the ovaries in the pelvic cavity. The tissue from both organs proved to be normal in structure under a close microscopic examination. The broad ligament was thicker and wider than is usually found in a female subject, due to the fact that the uterus was a little lower in the pelvis than normal. The uterus measured about 5 cm. in length, 4 cm. in width, and 2 cm. in thickness. A muscular wall, as well as a lumen which opened downward into the vagina, could be easily seen by both microscopic and macroscopic examinations. The oviduct took a normal course to the lateral angle of the uterus. A microscopic examination of the tube showed a lumen with walls containing the usual tunics. The cervix of the uterus passed into the inferior portion of the prostate about one-half inch below the urethra. The position of the organs might be described as follows: The bladder was superior and anterior to the uterus, with the prostate almost below the bladder, and a little anterior to the inferior portion of the uterus. Both are connected to the prostate, the urethra entering the prostatic substance near its superior anterior surface, the cervix of the uterus occupying the lower two-thirds. The cervix of the uterus held almost the exact position of the utriculus prostaticus of the male.

Externally the genitalia featured decidedly as a male. However, upon a closer examination of the region, and palpation of the organs, certain irregularities could be observed. The penis was small with a urethral orifice three-fourths as large as the organ itself. The opening gradually increased in size until it terminated at the cervix of the uterus. This portion of the urethra was in all respects a vagina attached to the inferior surface of the penis. Both the lumen of the uterus and the urethra opened directly into the vaginal opening.

It has been found in all true cases of hermaphroditism that there is always a sharp distinction between the male and female genital tissue and never an undefined mixing of the two elements (true ovitestis). In this unusual case we found the same phenomenon with a wider separation of the two kinds of tissue, the testes and ovaries in the exact position of a normal individual.

67. *Melanin pigment in the pigmented epithelium of the retina of the embryo chick's eye studied in vivo and in vitro.* DAVID T. SMITH (introduced by W. H. Lewis), Johns Hopkins Medical School.

A series of eyes, ranging from one day and eighteen hours to seventeen days of incubation, was studied. It was found that the granules were beginning to develop as early as forty-two hours. At this age a few small gray and colorless granules could be seen in the cytoplasm of the cell. These granules gradually increased in size, number, and depth of color until at seventeen days the cytoplasm was found to be densely packed with small, black, rod-shaped granules. In the intermediate stages, especially between three and five days, some practically colorless granules could be seen. Numerous granules of all possible shades of gray could also be seen. The individual granules were always homo-

geneous in color. The variations in size did not correspond to the variations in color, as very small black granules could be seen side by side with large gray ones.

It was found, in cultures, that the pigment granules moved in cytoplasm of the cell with a swift, jerky motion. This was in sharp contrast to the slow drifting movement of the mitochondria. The movement of the granules was found to be much accelerated by continuous exposure to light. The granules were collected in a large mass at one side of the nucleus, probably about the centriole. From this point some of the granules appeared to move in definite paths to and from the periphery of the cell. Others wandered aimlessly about in the cytoplasm.

The granules in the living cell did not stain with janus green. They stained quite readily with neutral red, and when grown in a medium which contained it they retain the red color even after fixation and mounting. In fixed preparations the granules were found to take both basic and acid stains.

These granules are very stable. The degeneration of the cell has apparently no effect on them. So resistant are they that even the small ones are not destroyed by cold, concentrated HCl.

There was no evidence that these granules were either developed from the mitochondria or extruded from the nucleus.

68. *The early recognition of sex from the external genitalia in human embryos 15 to 50 mm. long.* M. H. SPAULDING (introduced by G. L. Streeter).

As a result of the examination of a rather extensive series of human embryos to ascertain if there are any differences in the external genitalia by which the sex of the embryo can be recognized at an earlier period than has hitherto been possible, I have found that the embryos do not pass through a preliminary 'indifferent period' before assuming the characteristic male or female features, but, on the contrary, show certain differences, specifically male or female, almost from the first appearance of the genital tubercle.

The diagnostic point which I have found of value in recognizing the sex of embryos, at least as early as 15 mm., is the length of the urethral groove upon the posterior surface of the phallus. In males this groove extends to the tip of the phallus, whereas in females it stops proximal to the point where the future coronal sulcus will be formed.

69. *The development of the eyelids, lachrymal gland, extrinsic eye muscles, optic radiations and centers in individuals with a partial or complete absence of the eyeball.* CHARLES R. STOCKARD, Cornell University Medical College.

In a stock of guinea-pigs in which degeneracy has been experimentally induced, a series of individuals have been born which exhibit various degrees of ophthalmic defects. Several animals have shown complete absence of both eyes, others one perfect eye with complete absence of its

mate, and other specimens present intermediate steps in the disappearance of the eye.

Such specimens have furnished material for a study of the relationships in development between the retina or later eyeball and the accessory structures connected with the movement and function of the organ of vision.

The eyelids develop and all of their parts and structures are present in the absence of an eyeball, although the size and shape of the lids may be much modified. The lachrymal gland is often perfectly developed in an orbit in which an eye was never present. All of the accessory eye muscles are present with normal innervation and powers of contraction in some eyeless specimens. They move the mass of connective-tissue and conjunctival membrane to which they are related in a tangled fashion. The optic nerve and primary optic tracts are of course absent when the eye is absent, but in such cases the optic radiations and optic centers are seen to be structurally about the same as those found in the brain of a normal two-eyed guinea-pig.

It has further been found that an eyeball may persist for one or several years without an optic nerve connecting it with the brain. The retina, with the exception of the arrangement of the fibers from the ganglionic cells, may be perfect in such an eye, and probably receives images from surrounding objects without the possibility of conducting the effects to the brain.

70. *Variations of structural expression in the inheritance of polydactyly.*

CHARLES R. STOCKARD and G. N. PAPANICOLAOU, Cornell University Medical College.

The inheritance of polydactyly in a strain of guinea-pigs has been studied for the past several years. This character when it appears in the race is inherited as a Mendelian dominant.

The expression of the character in a series of individuals presents a most striking condition. The extra toe on the hind foot may be a perfectly developed functional toe in one animal, while in others the toe presents varying degrees of imperfect development and structure until in some it is represented by only a minute toe-nail attached to the foot by a thread-like filament. This poorly formed toe is frequently broken off or lost shortly after birth, and would often escape notice if not carefully looked for. Other animals inherit the extra toe, but fail to develop it sufficiently to show any evidence of its existence at birth. The fact that these have the character for extra toes is demonstrated by their offspring which may exhibit the toe as frequently as do offspring from parents with well-expressed polydactyly.

These normal variations in the expression of this dominant character renders it a most uncertain quantity for judging the influences of experimental treatments on its inheritable behavior in different groups of animals.

71. *Embryological significance of the crus helcis.* GEORGE L. STREETER, Department of Embryology, Carnegie Institute of Washington.

It has been supposed that the six auricular hillocks of the mandibular and hyoid arches form the primordia of and are directly converted into the various portions of the auricle. A more critical examination of these in a considerable number of human embryos leads to the conclusion that with perhaps the exceptions of the first which seems to enter into the formation of the tragus and the sixth into the formation of the antitragus, they lose their identity as hillocks before the definitive portions of the auricle make their appearance. The significance of these hillocks is therefore to be explained in some other way than as representing the primordia of the parts of the auricle.

The crus helcis makes its appearance in the region of the second and third hillocks of the mandibular arch in embryos about 18 mm. long. It eventually fuses with the helix proper, though always retaining a structural difference.

72. *The order, time, and rate of ossification of the skeleton. I. Birds.*

R. M. STRONG, Loyola University School of Medicine.

This is a preliminary report of some comparative studies of ossification in the Amphibia, Reptilia, birds, and Mammals. This paper deals only with the results which have been obtained with birds. Embryo chicks and ducks have furnished the larger portion of the data, but several wild species have been used.

The time when ossification begins in birds is remarkably constant, considering the great differences in the incubation period. Thus Kulczycki found ossification beginning in the clavicle of the canary on the seventh day, and not more than a day later in the chick. This corresponds with some observations I have made on small birds. Ossification begins hardly a day earlier in the chick than in the duck. Yet the canary has an incubation period of thirteen days, the chick twenty-one days, and the duck twenty-eight days. According to Broom, the ten-day ostrich embryo is about as far developed as a seven- or eight-day chick, though the ostrich has an incubation period of forty-two days.

Ossification begins almost simultaneously in the clavicle, humerus, radius, ulna, femur, tibia, and fibula, but not first in the clavicle as usually stated.

There is some variability in both the order and rate of ossification of the bones in different groups of birds, and slight variations occur in different individuals of the same species. The rate is ordinarily bilaterally symmetrical, but there are occasional small exceptions.

73. *Homoplastic thyroid transplants.* W. W. SWINGLE (introduced by C. F. W. McClure), Princeton University.

The following experiments were undertaken with the object of testing the view recently suggested by the writer that the long period of larval life of certain species of anurans is due to the slow rate of thyroid

development. *Rana catesbiana*, the bullfrog, has a larval life of about two years, and attains on the average a length of about 137 mm. at the time of metamorphosis.

Experiment 1. Two groups of giant tadpoles of the second year were starved sixty days. Group A averaged 137 mm., total length, had hind legs 40 mm. long, frog mouth, fore legs well developed but not yet through the skin of the pectoral region, no indications of tail atrophy. Group B averaged in length 123 mm., had neither fore nor hind legs or other indications of metamorphosis. The thyroid glands of the group A animals were grafted interperitoneally into the animals of group B. Result: Twenty-five days from the date of grafting the animals were in practically identical developmental stages as the animals from which the glands had been taken.

Experiment 2. Two pairs of thyroid glands of small, 60-mm., immature, first-year larvae, showing no indication of metamorphosis, were grafted into single large 125-mm. tadpoles without fore or hind legs. Result: No change after three months. Apparently the thyroids of such animals are inactive.

Experiment 3. Thyroid glands of large 130-mm. second-year tadpoles in early stages of metamorphosis were grafted into small, immature, 60-mm., first-year larvae. Result: Metamorphic changes up to, and slightly beyond those of the animals from which the glands had been taken within twenty-four days.

74. *A study of the supracondyloid process in the living.* ROBERT J. TERRY, Washington University Medical School.

Presence of the supracondyloid process can be recognized in the living and, when well developed, even in muscular and stout subjects. The examination of many subjects indicates that the occurrence of the process is probably not so frequent as has been reported from observation in the dissecting room. It has been found in the negro as well as in whites, and in both sexes. The question of its inheritance is included in this study.

75. *Age characters of the pubic bone.* T. WINGATE TODD, Western Reserve University.

Certain joints present a special relation to age. Adjacent to these joints articular epiphyses ossify incompletely, erratically, or not at all. As the plane between the bone and the articular cartilage of these joints displays features resembling in some degree those of the diaphyso-epiphyseal plane, it also, like the latter, may be used in the determination of age.

Of this group of joints the symphysis pubis is chosen first for presentation because the appearance of the bony symphyseal face in relation to age is almost constant. A study of it therefore is one of the most reliable guides to the age of the individual. It admits of an estimate correct to within five years of the ascertained age between twenty and forty, and to about five years between forty and seventy.

The standard sequence applicable to the majority of individuals is briefly the following:

- Formation and completion of dorsal border Age 22-26
- Formation and completion of extremities Age 25-33
- Formation and completion of ventral border Age 33-38
- Changes in symphyseal face and ventral surface pubis Age 38-40
- Secondary changes in same areas Age 50 and upward

There is a variant upon this sequence brought about essentially by the early formation and completion of the ventral border.

The material used for this study consists of between six and seven hundred human skeletons of known age, sex, and clinical history. The inclusion within this number of skeletons, male and female, of white and of negro hybrid races indicates that the observed features are age characters and not racial or sexual in type.

76. *Changes in the cells of the arachnoidea.* LEWIS H. WEED, Johns Hopkins Medical School.

It was noted in 1917 that the morphology of the lining cells of the subarachnoid space varied apparently with physiological activity. These earlier observations were extended by Essick and Ayer in studies of the response of the arachnoidal cells to abnormal stimuli. Under such conditions, hypertrophy and hyperplasia of the cells occurred, and in the final stages the cells budded off to become free phagocytic elements in the subarachnoid space.

A more frequent change in the morphology of these arachnoidal cells, observed in adult and old cats, first shows itself as a localized proliferative process; small nodular accumulations of the cells are found distributed somewhat unevenly over the arachnoidea. On section these cell accumulations appear as dense masses with nuclei usually closely approximated. These cell clusters apparently may continue to increase in size, remaining well differentiated from the adjacent unchanged arachnoid membrane. In other animals the proliferative process extends somewhat diffusely over the membrane, but more commonly the nodular swellings attain a definite size and then show alternative changes of either degeneration or more outspoken proliferation. The degenerative process is characterized by calcification, either in amorphous depositions or in ring formations. The extreme proliferative process results in so-called endotheliomata, two of which have been found in a small series of old cats.

The evidence indicates that the morphology of the covering cells of the arachnoidea depends not only on the physiological state of the membrane, but also upon the age-condition of the particular animal.

77. *Studies on minute innervation of ductless glands.* H. O. WHITE, Medical Department, University of Southern California.

This investigation was undertaken in consequence of frequent erroneous interpretations by the medical student during the laboratory course

of normal histology on ductless glands, that certain thread-like structures represent perhaps part of the nerve distribution to the tissue under observation. A survey of even the latest text-books and meager literature on that subject does not fail to impress one with the fact that the minute innervation of the ductless glands merits a more detailed investigation.

With this in mind, it is intended to study all ductless glands, and the spleen of the cat (*Felis domestica*) was selected as a type, due primarily to the apparent difficulty of obtaining fresh human material, and, secondly, that in it as well as in that of the dog and pig, there is a more abundant and more accentuated admixture of smooth muscular elements than in any other of the mammalian ductless glands. The further object of this study, however, is chiefly to collect, if possible, data for a comparative investigation from an histological and possibly physiological standpoint, since both the sympathetic and the cerebrospinal systems innervate the ductless glands, and this will form the subject of a subsequent communication. The spleen from a freshly killed cat was carefully dissected in situ, paying particular attention to the hilus where the nerves and blood-vessels enter and leave that organ.

Painstaking search under the high magnification with the oil-immersion objective will reveal nerve filaments within the trabeculae, and if traced for some distance may be seen here and there to break into still finer elements which finally appear to become lost among the peripheral cells of a Malpighian body. Whether or not the finer filaments extend also into the center and there terminate in some special manner was thus far difficult to ascertain.

78. The origin and relationship of the bronchial artery in the guinea-pig.

H. S. WILLIS (introduced by A. K. Krause), Johns Hopkins Hospital.

The bronchial artery in the guinea-pig arises differently from that heretofore described as characteristic for most mammals. In this animal a short trunk arises on each side from the subclavian artery and supplies the cephalic intercostal spaces. It is from this vessel on the right side that the bronchial artery arises. This vessel supplies the trachea, esophagus, the lymph nodes at the hilum, at which point it penetrates the lung. In the lung there are occasional though definite anastomoses between the bronchial and pulmonary arterial systems.

Branches from the bronchial artery pass freely into the wall of the pulmonary artery and constitute the vasa vasorum of the pulmonary artery. This is possible because the pulmonary artery and the bronchus lie everywhere in close apposition one to the other.

It is demonstrated also that branches of the bronchial artery pass to the collections of lymphoid tissue throughout the lung and constitute the sole blood supply of this tissue.

DEMONSTRATIONS

1. *Series of histological preparations, showing the development of the eyelids of the albino rat, from the time of fusion until the completion of disjunction.* WILLIAM H. F. ADDISON and HAROLD W. HOW, University of Pennsylvania.
2. *Grafts of metanephros in the allantois.* RUTH RAND ATTERBURY (introduced by Vera Danchakoff), Columbia University.
3. *Models illustrating the early development of the cloaca in chick embryos.* EDWARD A. BOYDEN, Harvard Medical School.
4. *Radiograms and tracings for a radiographic atlas of the human body.* H. S. BURR, Yale Medical School.
5. *a. Microscopic sections demonstrating bone and muscle origin of the hind limb of the pig. b. Microscopic sections demonstrating early histogenesis of the descending colon of the pig.* EBEN J. CAREY, Creighton Medical College.
6. *Nerve endings of sensory type in the muscular coat of the alimentary canal.* F. W. CARPENTER, Trinity College.
7. *Aseptic inflammation in the tails of living amphibian larvae.* E. R. CLARK and E. L. CLARK, University of Missouri.
8. *Preparations illustrating a case of true lateral hermaphroditism in the pig, with functional ovary and immature testis.* GEORGE W. CORNER, Johns Hopkins Medical School.
9. *a. Myeloid metaplasia of the mesenchymal stroma in different organs of the chick embryo. b. Ingestion and digestion of tumor cells by mesenchymal plasmodia.* VERA DANCHAKOFF, Columbia University.
10. *Development and differentiation of hemopoietic foci around the aorta and the coeliac artery in the chick embryo.* VERA DANCHAKOFF and MAURICE RICHTER, Columbia University.
11. *The B N A arranged on the basis of regional anatomy.* VICTOR E. EMMEL, Department of Anatomy, University of California.

In the present work the systematic B N A has been expanded to include a correlated regional arrangement of these anatomical terms based upon the sequence in which the corresponding structures may be encountered in actual dissection. During the past year mimeograph copies of the work were sent to anatomists interested in gross anatomy for examination and criticism. This work, together with a series of figures for surface anatomy and surface projections of the skeleton, is placed on demonstration for the purpose of critical discussion as to the utility of this or some other method for the presentation of a regional arrangement of the B N A terms.

12. *The morphological elements in the blood of *Batrachoseps attenuatus**

VICTOR E. EMMEL, Department of Anatomy, University of California.

Haematological preparations demonstrating: the unique occurrence of great numbers of non-nucleated erythrocytes, their structural characteristics and evidences as to their mode of origin from the nucleated corpuscles; comparisons with erythrocytic conditions in mammals; the free cytoplasmic elements or blood-platelets; certain cytological characteristics of the eosinophiles; mast cells and their behavior in the circulating blood.

13. *The free granules (chylomicrons) of fresh blood under the dark-field microscope. a. Blood from a fasting individual (few chylomicrons).*

b. Blood two to three hours after a full meal (many chylomicrons).

S. H. GAGE, Cornell University.

14. *Sections of suprarenal gland and hypophysis cerebri showing specific action of dichlorodiethyl sulphide.* B. C. H. HARVEY, Hull Laboratory of Anatomy, University of Chicago.

Guinea-pigs were given doses of this oil, of from 0.004 to 0.7 gram per kilogram of body weight. They lived from one day to twenty-five days, but ultimately became very sick and died. After they showed serious effects of poisoning, solutions of sodium ferrocyanide and of iron and ammonium citrate (green scale) were given subcutaneously.

Under these conditions, cells of the medulla of the suprarenal and of the anterior lobe of the hypophysis contained much Prussian blue. None was found in the cortex of the suprarenal or in the other lobes of the hypophysis. The stomach, liver and kidney each contained a little. Cyanimin, neutral red, and other indicators have so far failed to show clear evidence of the presence of acid in these cells.

15. *Photographs, microscopic sections, etc., to show the caudal filament and the condition of rumplessness in the chick.* GEORGE B. JENKINS, Carnegie Laboratory of Embryology.

16. *Models illustrating the development of the human urethra.* FRANKLIN P. JOHNSON, University of Missouri.

17. *Histological preparations of jaw-bone of new-born cat, showing osteoclasts containing globules of osseous material.* H. E. JORDAN, University of Virginia.

18. *Demonstration of the 'Schollen' leucocytes (Weil) from the digestive mucosa of the sheep.* Miss L. KEASBEY (introduced by B. F. Kingsbury), Cornell University Medical College.

19. *Erythropoiesis in the ileum of the rabbit.* JOHN S. LATTA (introduced by B. F. Kingsbury), Cornell University Medical College.

20. *Histological demonstration of fat contained in the mucosa of the alimentary tract of cats which were fed a fat-free ration.* WILLIAM A. MCINTOSH, Johns Hopkins Medical School.
21. *Models and drawings of the skull of a human fetus of 43 mm.* CHARLES C. MACKLIN, Johns Hopkins Medical School.
22. *The venous system of the 20-mm. pig embryo.* H. P. MUIR (introduced by F. P. Johnson), University of Missouri.
Drawing made from a graphic reconstruction, showing the plexuses, sinuses and veins, chief among which are the following:
Plexuses: Plexus durae matris anterior, plexus durae matris medialis, plexus durae matris posterior.
Sinuses: Sagittalis superior, transversus, rectus, petrosus superior, and cavernosus.
Venae: Jugularis interna et externa, ulnaris primitiva, cardinalis posterior, azygos, thoracoepigastrica, pulmonalis, intercostalis suprema, cava inferior, umbilicalis dextra et sinistra, porta, mesenterica superior et inferior, subcardinalis, caudalis, and fibularis primitiva, and the ductus cuvieri.
23. *Model of the spiracular sense-organ of Squalus acanthias.* H. W. NORRIS, Grinnell College.
24. a. *The origin and structure of the cells of the taches laiteuses in the omenta of new-born and adult rabbits.* b. *The origin of lymphoid wandering cells from the endothelial and perithelial cells of degenerating blood-vessels.* EMILY H. PAYNE (introduced by Hal Downey), University of Minnesota.
25. a. *An ocular ruling for microscopic sketching.* b. *A graphic level reconstruction and series of a sixteen-day chick with a persistent left aortic arch.* c. *The elastic opercular ligament of the frog and the elastic incudal ligaments in the cat.* A. G. POHLMAN, Saint Louis University.
26. *Materials illustrating the effects of lack of oxidation on the eyes and brain of chick embryos developed in nitrogen atmosphere or treated with cold.* C. W. M. POYNTER, University of Nebraska Medical School.
27. a. *Preparations illustrating the endogenous origin of the eosinophil leucocyte granules in the eosinophils of sheep hemolymph nodes.* b. *Material illustrating the results obtained after the injection of antigens into the body cavity of guinea-pigs.* ADOLPH R. RINGOEN, Hematological Laboratory, University of Minnesota.
28. *Specimens showing the regeneration of blood-vessels after intestinal anastomoses.* FLORENCE R. SABIN, Johns Hopkins Medical School.

29. *Graphs illustrating the postnatal growth of the various human organs.*

RICHARD E. SCAMMON, University of Minnesota.

A series of curves illustrating the changes in absolute and relative weight of the various organs of the body from birth to the close of the second decade, also graphs illustrating the types of organ-growth found in postnatal life.

30. *Graphs illustrating the changes in gastric capacity in the neonatal period of man.* RICHARD E. SCAMMON and LAWRENCE DOYLE, University of Minnesota.

Graphs showing the anatomic and physiologic capacity of the stomach in the new-born and in the first ten days of life. Curves showing the relation of gastric capacity to body weight and parity, and the effect of supplemental feeding on physiologic capacity.

31. *Materials illustrating the postnatal changes and growth of the middle ear in man.* J. L. ROGERS (introduced by R. E. Scammon), University of Minnesota.

Corrosion preparations, radiographs, and figures showing the size and topography of the middle ear in the infant, child and adult.

32. *Graphs illustrating the variability in standing height, body weight, and the height-weight index in early maturity.* G. B. SCHILL (introduced by R. E. Scammon), University of Minnesota.

33. *Graphs and models illustrating the prenatal growth of the nasal cavities and nasopharynx in man.* F. N. KNAPP (introduced by R. E. Scammon), University of Minnesota.

34. *Models and graphs of the development and growth of the abdomen and abdominopelvic cavity in prenatal life.* HELEN MACKEEN (introduced by R. E. Scammon), University of Minnesota.

35. *Graphs illustrating the growth of the human fetus.* LEROY A. CALKINS (introduced by R. E. Scammon), Department of Anatomy and Department of Obstetrics and Gynecology, University of Minnesota.

A series of graphs based upon the determination of seventy-five lineal measurements and circumferences on some four hundred preserved fetuses. The preservation of the specimens was carried out in one of two ways. Those under 35 cm. total body length were preserved in 10 per cent formalin alone. Those over 35 cm. were first injected through the umbilical vein with varying amounts, usually about 30 per cent of body weight, of a 10 per cent formalin solution containing 1 per cent chromic acid, and then kept in a 10 per cent formalin solution. The technique of measurement employed was closely adapted to that recommended by the International Congress of Anthropologists

at Monaco (A. Hrdlička, *Am. Jour. Phys. Anthrop.*, vol. 2, no. 1, Jan.-Mar., 1919).

The graphs, with resulting curves, were, in all cases, plotted against the total body length. The curves approximate straight lines except in the case of the so-called obstetrical measurements of the head, wherein there is a deflection toward the horizontal beginning in the vicinity of 35 to 40 cm. standing height. This deflection may be due to birth molding of the comparatively mature head. It is therefore probable that each external measurement of the fetal body, in the period observed, always bears a definite relationship to the total body length.

A further study is being conducted to ascertain the effects of the different methods of preservation and the corrections necessary for the application of the results obtained to fresh material. The exact effect of birth molding is also being studied.

36. *Some points in the anatomy of the okapi.* H. VON W. SCHULTE, Creighton University.

37. *Microscopic sections showing the effect on lymphoid tissue of feeding young kittens on diets differing in fat content.* E. L. SETTLES (introduced by E. R. Clark), University of Missouri.

Two kittens from the same litter were fed for four and a half months—one on milk containing approximately 6 per cent fat, the other on an equal quantity of milk containing approximately 3 per cent fat, supplemented in the former by fat meat, and in the latter by lean meat. The health of both remained excellent throughout.

There is a striking difference in the lymphoid tissue, particularly in the pharyngeal tonsils, Peyer's patches, mesenteric lymph glands and thymus. Macroscopically, microscopically, and by weight, the lymphoid tissue is decidedly greater in the cat receiving the higher fat diet.

38. *The tectorial membrane and organ of corti of a one-day rat.* HUBERT SHEPPARD (introduced by G. E. Coghill), University of Kansas.

39. *Microscopic preparations of the ovary, oviduct, uterus, testis, and vas deferens of a human hermaphrodite.* HUBERT SHEPPARD (introduced by G. E. Coghill), University of Kansas.

40. *The posterior spinal cord of the flounder, showing collection of large irregular cells (homologous to glandular cells in the spinal cord of the skate).* C. C. SPEIDEL (introduced by W. H. F. Addison), St. Lawrence University.

41. *Microscopic preparations showing the ear-swimbladder relation and the maculae acusticae of clupeoids.* H. C. TRACY, Department of Anatomy, University of Kansas.

42. *Models showing the topographical development of the pelvis in human embryos.* JOHN WARREN, Harvard Medical School.

43A. *Microscopic sections of the cat's spleen, showing nerve filaments among the peripheral cells of malpighian bodies.* H. O. WHITE, University of Southern California.

43B. *Human cerebral circulation.* H. O. WHITE, University of Southern California.

A comparatively fresh cadaver is injected through both common carotid arteries with a four- or five-gallon solution composed of formalin, 20 per cent, and glycerin, 3 per cent. After the injection, both arteries are clamped above the points of incision and the clamps left in situ for about five days, when a coloring material composed of starch, gelatin, and English vermilion dissolved in hot water to the consistency of syrup is injected through the same openings. The arteries are again clamped, the head severed from the body, the vertebral arteries clamped to prevent the outflow of the coloring fluid, and after the expiration of about two to three weeks, during which time the entire head is kept in a 5 per cent solution of formalin, the brain can be removed and the entire arterial supply shelled out, as it were.

44. *Bladder epithelium in contraction and distention.* O. H. GAEBLER (introduced by E. R. Clark), University of Missouri.

45. *Demonstration of methods of using photographs as an aid in examinations for anatomical courses (gross anatomy, histology, neuro-anatomy, embryology)* HENRY MC. E. KNOWER, Medical College, University of Cincinnati.

Each student receives three or four photographic prints, reduced copies of pictures of special views from text-books, atlases, etc. The pictures should not be overreduced, and sufficient margins should be left for writing on all sides.

These prints may be used in different ways, with almost endless variations. A correct statement of the particular aspect of objects presented, with lines drawn by the examiner or by the students to point out details which must be named in the margin by the students, will be found to furnish the simplest test of practical familiarity with specimens. Such written statements may be placed on a separate sheet, reference being made to numbered points on the prints. The examiner may have the class draw a few muscles or other structures on a picture of the skeleton. Nerves or vessels, or even organs may be put in when not shown. Explanation may be demanded of disturbed relations or novel views. A statement may be required of what has been removed from a given area in a dissection or what organs lie beneath it.

The students write their names on their prints and drop them in a box as they leave the room.

Similar tests may be applied to many aspects of histology, neuro-anatomy, or embryology. Where large classes are to be tested in practical knowledge of different aspects of specimens, marking or discussing photo-prints, is a great convenience; the entire class being subjected to the same tests, thus making comparisons easier. At the same time, a practical object lesson is furnished in methods of observing and relating details, etc., and the instructors are furnished with reliable records.

Of course there is no intention of substituting pictures for actual specimens. It can easily be shown that only by studying real specimens in the laboratories can students properly interpret such photographs as are used, with appropriate questions.

46. *The distribution of smooth muscle in the hepatic veins of mammals.*

L. B. AREY and J. P. SIMONDS, Northwestern University Medical School.

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Escuela Médica de la Universidad de San Luis

Retención de fetos muertos en el útero y su importancia en los problemas de la superfetación y superfecundación

El autor describe dos casos en el gato y uno en el perro, en los cuales el útero estaba ocupado por fetos que diferían marcadamente en tamaño y grado de desarrollo. El autor suministra pruebas que indican que en todos estos casos los óvulos que produjeron los fetos de diferente tamaño fueron liberados en el mismo periodo de ovulación, siendo fecundados e implantándose en el útero próximamente al mismo tiempo. Los fetos menores fueron retenidos en el útero como cuerpos muertos durante tiempo suficiente para establecer diferencias en el tamaño y grado de desarrollo de ambas clases de fetos. Puesto que fetos muertos pueden retenerse en el útero durante periodos relativamente largos sin sufrir considerable autolisis y absorción, el autor indica que, en la mayor parte de los casos descritos en los cuales existen simultáneamente en el útero fetos que difieren marcadamente en el tamaño y grado de desarrollo, la conclusión de que ha habido superfetación o superfecundación no está garantizada por los hechos.

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RETENTION OF DEAD FETUSES IN UTERO AND ITS BEARING ON THE PROBLEMS OF SUPERFE- TATION AND SUPERFECUNDATION

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THREE FIGURES

INTRODUCTION

Collectors of embryological material are familiar with the fact that occasionally in mammals a pregnant uterus contains fetuses of unequal size and development. In such instances it is not uncommon to find that the smaller fetus or fetuses are blighted and show advanced retrogressive changes indicating progressive autolysis and absorption. So commonly has such been the case that there exists a general impression that a dead fetus may not long remain intact in the uterus, despite fairly conclusive evidence to the contrary.

Not a few cases have been reported by medical practitioners in which two human fetuses of unequal size and development were aborted or a dead fetus of less than full term was delivered with a living fetus. Although in many of these cases the smaller fetus was described as abnormal in appearance and more or less macerated, it seemed impossible to believe that it had been carried as a dead body in the uterus long enough to account for the difference in size and degree of development of the two fetuses if the ova which gave rise to both were fertilized and implanted approximately at the same time. Therefore, the great majority of these cases have been interpreted as cases of superfetation.

The older literature reveals relatively few cases in mammals other than man which have been interpreted either as indicating superfetation or superfecundation. More recently King ('13)

reported several cases in rats in which she believes superfecundation occurred and at least two cases in which she believes superfetation occurred. Harmon ('17, '18) reported the case of a cat which she interpreted as indicating superfetation and a 'probable case of superfetation' in the cow. Hunt ('19) also reported a case which he interpreted as indicating superfetation in the cat.

In 1916 the writer published a brief paper in which two cases of apparent superfetation in the cat were described.¹ Microscopic study of these cases afforded no evidence that superfetation had occurred, but indicated clearly that the ova which gave rise to the larger and the smaller fetuses, in both cases, belonged to the same period of ovulation and were, doubtless, fertilized and implanted approximately at the same time. In one case the smaller fetuses were obviously retained as dead bodies in the uterus for a considerable period without undergoing marked retrogressive changes. In the other case the smaller fetuses which were still very young when life ceased were obviously undergoing autolysis and intra-uterine absorption. The present paper is based on the material afforded by these two cases and the case of a dog secured recently in which a small dead fetus was delivered with other full-term fetuses. It is an attempt to demonstrate more clearly that dead fetuses are sometimes retained in the uterus for relatively long periods without undergoing marked macroscopic changes and to emphasize the relation of this fact to the general problems of superfetation and superfecundation.

MATERIAL DESCRIBED

Case 1. This cat was killed with illuminating gas for laboratory purposes. The uterus was found to be pregnant with two fetuses of nearly full term and two smaller ones approximately 10 mm. in length. One larger and one smaller fetus were located in either horn of the uterus, the larger one just above the bifurcation, the smaller one somewhat farther anteriorly. The vesicles containing the smaller fetuses were less than one-fourth

¹ Interstate Medical Journal, vol. 23, pp. 204-214.

the size of those containing the larger ones. The uterine placentae of the larger fetuses were highly vascular; those of the smaller ones showed relatively smaller blood-vessels, but apparently were well supplied with blood. By reason of the great difference in the size of the vesicles, the smaller size of the blood-vessels supplying the uterine placentae of the smaller fetuses was not considered of particular significance. The gross appearance of the uterus with the four vesicles in situ seemed to indicate clearly a case of superfetation.

Examination of the fetal membranes both of the smaller and the larger fetuses showed them to be intact and turgid with the contained fluid. The fetal placentae of the smaller fetuses were less vascular than those of the larger ones and the amniotic fluid in the smaller vesicles was slightly coagulated.

The smaller fetuses and parts of their placentae as well as both ovaries of the cat were removed and immediately placed in Zenker's fluid. The smaller fetus in the right horn of the uterus measured 10 mm. in length. It was perfectly intact, but appeared slightly older than a normal 10-mm. embryo. The trunk was somewhat straighter, the head also was deflected to a lesser degree and the mouth was open. The smaller fetus in the left horn of the uterus measured 9 mm. in length. The head and the rest of the body showed a slight disproportion in size. The head also was deflected to a lesser degree than that of the other smaller fetus, the mouth was open and there was a slight distortion in the lumbar region. The general appearance of this fetus indicated a stage of development somewhat less advanced than that of the smaller fetus in the right horn of the uterus. Both smaller fetuses are illustrated in figures 1 and 2.

Both fetuses were cut in serial sections and stained by the ordinary haematoxylin-eosin method. Upon microscopic examination the tissues show well-marked necrotic changes; however, all the embryonic structures indicate a normal early development. The fundamentals of the organs are clearly recognizable. As is characteristic of necrotic tissues, the nuclei fail to respond normally to basic stains. The majority of the nuclei retain their normal form, but the stainable chromatin material con-

tained in them is appreciably less than normal. The cytoplasm also shows retrogressive changes, but there is little evidence of autolysis.

The retrogressive changes following the cessation of life are perhaps most marked in the central nervous system. The characteristic arrangement of nervous and supporting elements is not apparent. The ependymal layer is somewhat fragmented and the entire canal including the cerebral vesicles is more or less completely filled with partially fragmented cells and tissue debris. Many of the spinal ganglion cells reached a stage,

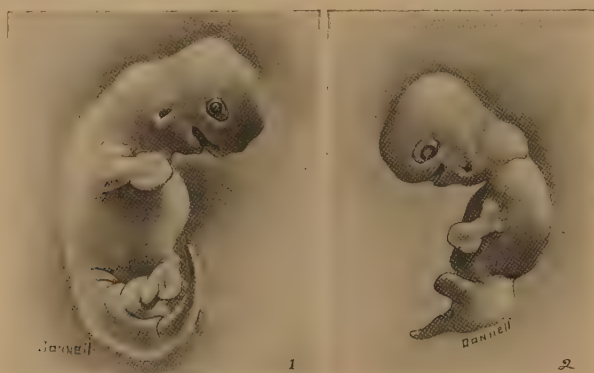


Fig. 1 Dead fetus located in right horn of uterus, case 1, actual length 10 mm.

Fig. 2 Dead fetus located in left horn of uterus, case 1, Actual length 9 mm.

before becoming necrotic, in which they may be recognized as neuroblasts. Spinal nerves may be traced peripherally, but their fibers are fragmented.

Other embryonic structures show only less marked retrogressive changes. The endothelium of the heart and the blood-vessels is no longer intact. Endothelial cells and fragments of mesenchymal tissue occur among the blood-cells in their lumina. Blood-cells also occur scattered throughout the tissues. The epithelial lining of the digestive tube shows considerable fragmentation. The cells in the epidermis lack their characteristic arrangement; however, the epidermis is nowhere completely destroyed.

The amnion was apparently well preserved, but microscopic examination reveals extensive necrosis. In some areas the epithelium is no longer intact and the amniotic mesoderm shows evidence of hyaline degeneration. The placental chorion shows extremely few blood-vessels. Parts of the chorionic epithelium are desquamated. The chorionic villi, which are of the type commonly found in young placentae, show more extreme degeneration than do either amnion or chorion. Syncytial and basal layers cannot be clearly differentiated in the partially disintegrated epithelium, while in many areas the epithelium is entirely wanting. The villi are immediately surrounded by a fibrinous network of varying density which in many instances replaces the epithelium, and little blood remains in the intervillous spaces. In the decidua basalis there is a striking absence of blood in the sinuses and all blood vessels are relatively small.

Microscopic examination of the ovaries revealed in each two large corpora lutea of pregnancy all of which showed the same phase of development, indicating that four ovarian follicles ruptured during the last period of ovulation. Doubtless, the four ova extruded gave rise to the four fetuses contained in the uterus.

Case 2. This cat also was killed with illuminating gas for laboratory purposes. When the abdominal cavity was laid open the uterus was found to contain four vesicles of unequal size. The fetuses in the two larger vesicles were 70 mm. in length. The two smaller vesicles represented a stage of development not much later than the closure of the neural tube. One of the larger vesicles was located in either horn of the uterus just above the bifurcation; one of the smaller ones was located in either horn of the uterus between the larger vesicle and the junction of the Fallopian tube with the uterus. The smaller vesicles seemed to be quite as well supplied with blood as the larger ones. The difference in the size of the blood-vessels associated with the larger and the smaller vesicles was less marked in this case than in the case described above. The gross appearance of the uterus with the four vesicles in situ seemed to indicate superfetation even more clearly in this than in the preceding case.

Both ovaries of the cat, the smaller vesicles and parts of the uterine placentae associated with them were fixed in Zenker's fluid, sectioned, stained and examined microscopically.

One of the smaller vesicles contained only the merest remnant of an embryo. In the other was found a very young embryo which showed almost complete absence of differentiation (fig. 3). The embryonic tissues show less advanced necrotic changes than do those described in the preceding case; however, these tissues are obviously undergoing autolysis and absorption. That autolysis and absorption were in progress in this case is indicated also by the absence of all but a remnant of an embryo in one of



Fig. 3. Photomicrograph of a section of one of the uterine vesicles containing a small dead fetus, case 2. *E.*, remnant of embryo.

the vesicles. The entire picture presented by these smaller vesicles indicates very early cessation of development and prompt initiation of retrogressive changes.

Both amnion and chorion were apparently well preserved, but show microscopic evidence of early necrosis. Well-marked retrogressive changes are not yet apparent in the placental tissues. Each ovary contained two corpora lutea of pregnancy all of which show the same microscopic picture. They had not yet attained their maximum development, but show evidence of normal growth. They are highly vascular, the luteal cells are relatively large and show evidence of active proliferation. Obviously, these corpora lutea are of the same age; consequently,

two follicles in either ovary must have ruptured at the last period of ovulation. Doubtless, the four ova extruded gave rise to the four fetuses contained in the uterus.

Case 3. On March 25, 1919, a female dog was subjected to an operation, under general anesthesia, in which the inferior mesenteric ganglia and the left ovary were removed through an abdominal incision. The uterus was found to be pregnant with six fetuses, three of which were located in either horn. The enlargements of the uterus containing the embryonic vesicles were approximately of equal size and indicated vesicles approximately 2 cm. in length. All of the uterine placentae were highly vascular and normal in appearance. The dog made an uneventful recovery from the operation and, on April 29th, gave birth to her litter. Four full-term fetuses, two of which were living and two dead when found, and one dead fetus of less than full term were taken from the cage. No more fetuses were found in the cage later; thus, one of the fetuses present in the uterus at the time of operation remains unaccounted for. The average weight of the four full-term fetuses was 102 grams. The weight of the premature dead fetus was 40 grams. The skin of this dead fetus, which was still without hair, was intact and not appreciably macerated. Small pieces of the heart, the liver, the intestine, and the integument were prepared for microscopic study. All of the preparations showed that the tissues were well preserved, but obviously necrotic. The cells fail to respond normally to basic strains. The majority of the nuclei observed retain their normal form, but contain relatively little stainable material. The cytoplasm is somewhat fragmented, but there is no evidence of autolysis or absorption. Even the surface layers of the skin are not completely disintegrated and the stratified squamous character of the epidermis is still apparent. The necrotic condition of these tissues indicates that the fetus was dead for some time, but retrogressive changes were initiated tardily and progressed very slowly.

How long this fetus was retained in the uterus as a dead body cannot be determined; however, it is safe to conclude that sufficient time elapsed between its death and its delivery to account

for much greater destruction of tissue than is apparent if autolysis and absorption or decomposition had not progressed very slowly. Neither is there any evidence that the presence of this dead fetus hastened the delivery of the other fetuses. If it had not been determined incidentally that all of the fetuses present in the uterus were in the same phase of development during the early part of the period of gestation, this case might reasonably be classified with many cases which have been interpreted as cases of superfetation.

DISCUSSION

In the three cases described above, each of which, if it had not been critically examined, might reasonably be classified with the great majority of the cases which have been interpreted as cases of superfetation, the possibility of superfetation is precluded. In the first two cases the presence in the ovaries of as many corpora lutea of pregnancy all in the same phase of development as there were fetuses in the uterus indicates that the ova which gave rise to all the fetuses were extruded at the same period of ovulation. It might be argued in case 1 that even though one of the follicles in each ovary ruptured at a later period of ovulation than the other, the corpus luteum of this follicle might still have attained the same degree of development as that of the other and show the same microscopic picture. While this possibility must not be overlooked, it is highly improbable, in view of the early phase of development represented by the smaller fetuses, that these corpora lutea are not of the same age. In case 2 none of the corpora lutea of pregnancy have attained their maximum development and all show evidence of active normal growth. Obviously, all of these corpora lutea are approximately of the same age. In the third case all of the embryonic vesicles were observed to be approximately of equal size thirty-five days before parturition. Therefore, in this case, both superfetation and superfecundation are precluded. While it is conceivable and even probable that the development of the smaller fetus in this case was retarded for some time before life ceased, the necrotic condition of its tissues indicates that death

must have occurred a good while before delivery. Doubtless, it is safe to conclude that this fetus was retained in the uterus as a dead body long enough to account for much more advanced retrogressive changes than were actually observed if autolysis and absorption had not been retarded.

While in cases 1 and 2 described above the possibility of superfetation is precluded by the fact that the ova which gave rise to all the fetuses contained in the uterus were extruded at the same period of ovulation, the possibility of superfecundation must not be overlooked. As is well known, ova may, under favorable conditions, remain viable in the female genital tract for remarkably long periods. Therefore, it is conceivable that any ova which failed to be fertilized following the introduction of the spermatozoa which fertilized the ova which gave rise to the larger fetuses might still be fertilized by spermatozoa introduced later. This possibility is practically precluded in these cases by reason of the fact that the larger fetuses were located nearest the bifurcation of the uterus; consequently, both cornua of the uterus were early occluded by the vesicles containing the larger fetuses. Therefore, if sufficient time elapsed between the fertilization of the ova which gave rise to the larger and those which gave rise to the smaller fetuses to account for the difference in the phase of development represented by the larger and the smaller fetuses, fertilization of the later ova must have taken place long after the horns of the uterus were occluded by the larger vesicles and the ascent of spermatozoa rendered impossible. If we admit the possibility of deferred fertilization in these cases we must assume that the later ova were fertilized by spermatozoa which were present in the uterus soon after the first ova were fertilized, i.e., both ova and viable spermatozoa were present in the uterus or the Fallopian tubes for a period representing the difference in the degree of development of the larger and the smaller fetuses. Manifestly, this possibility does not merit serious consideration. Therefore, we must conclude that in both these cases the ova which gave rise both to the larger and the smaller fetuses contained in the uterus were fertilized and implanted approximately at the same time.

As pointed out above, the dead fetuses in case 2 were obviously undergoing autolysis and absorption. If this cat had lived until the normal termination of pregnancy, these fetuses would probably have been completely absorbed. In case 1 autolysis and absorption of the dead fetuses were progressing so slowly that even though the period of gestation were much longer than it is in the cat these fetuses would probably not have been absorbed, but would have been carried as dead bodies in the uterus until the normal termination of pregnancy.

The observations of not a few investigators, including Strahl and Henneberg ('12), Frankel ('03), and Meyer ('12), indicate that intra-uterine death of one or more fetuses among others which continue to live in the uterus is very commonly followed by retrogressive changes which progress rapidly in some instances and more slowly in others. It is significant in this connection that among over 2000 human abortuses in the Mall collection Meyer ('19) found "only a few specimens of almost complete intra-uterine absorption." He states, "it is often surprising how long the form of a small retained fetus or even the amnion has been preserved, although it should be remembered that in some cases the preservation of external form gives little indication of the true state of the constituent tissues."

Doubtless, in all cases in which a dead fetus is retained in the uterus retrogressive changes are initiated more or less promptly; however, in some cases autolysis and absorption progress so slowly that although extensive necrosis of the tissues occurs, very little absorption takes place and the external form of the fetus remains fairly well preserved. In these latter cases dead fetuses may remain apparently well preserved and intact for a relatively long period, indeed for a longer period than usually intervenes between the death of such fetuses and the termination of pregnancy. A discussion of the causes which are responsible for the rapid retrogressive changes in some cases and the slow retrogressive changes in others is not within the scope of this paper.

It is not the writer's purpose in this paper to discuss the possibility of the occurrence of superfetation or superfecundation,

but rather to emphasize the necessity of critically examining all of the evidence in each case in which fetuses of unequal size and development occupy the uterus contemporaneously before attempting to explain this phenomenon, and to point out the fact that the great majority of these cases admit of a simpler and more reasonable interpretation on the assumption that dead fetuses were retained in the uterus for relatively long periods than on the assumption that one or more ova were fertilized and implanted in a uterus which was already pregnant with one or more fetuses in a more or less advanced stage of development.

Obviously, if we must admit that dead fetuses may be retained in the uterus for relatively long periods without undergoing complete autolysis and absorption or decomposition, the great majority of the human cases which have been reported, but not critically examined, in which two fetuses differing in size were aborted or a dead fetus of less than full term was delivered with a full-term child, do not warrant the conclusion either that superfetation or superfecundation has occurred. The meager description of the gross appearance of the smaller fetus incorporated in the reports of many of these cases also suggests that a considerable interval may have elapsed between its death and its expulsion from the uterus. In these reports the abnormal and more or less macerated appearance of the smaller fetus is commonly attributed to postmortem changes either immediately preceding or following delivery. However, in view of the facts stated above, there is no conclusive evidence that these are not cases of true twin pregnancy.

In this connection several cases in mammals other than man reported recently are not without interest. Harmon ('17) described the case of a cat in which a fetus 10 mm. in length occupied the uterus contemporaneously with three other fetuses about 90 mm. in length and apparently near full term. The larger and smaller fetuses in this case represent approximately the same phases of development respectively as those in case 1 described in this paper. As no microscopic study of the fetal and placental tissues was made, Harmon's conclusion that this is a case of superfetation was based on gross appearances. There is no evidence presented in this case which precludes the

possibility that the ova which gave rise both to the larger and the smaller fetuses were extruded at the same period of ovulation and were fertilized and implanted approximately at the same time.

The case of 'probable superfetation' reported by Harmon ('18) in which a cow delivered a dead fetus of somewhat over four months' gestation four days after she had given birth to a normal calf does not differ essentially from the feline case cited above. In the absence of any detailed description of the dead fetus or a microscopic study of its tissues, there is no conclusive evidence that the development of both fetuses was not initiated approximately at the same time.

Hunt ('19) described the case of a cat in which a fetus 14.1 mm. in length was delivered with at least one other fetus of practically full term. In this case also the phases of development represented by the larger and the smaller fetuses respectively do not differ greatly from those represented by the larger and the smaller fetuses in case 1 described in this paper. The microscopic appearance of the tissues of the smaller fetus, as described by Hunt, suggest retrogressive changes similar to those observed in the smaller fetuses in case 1 referred to above, but perhaps less advanced. Hunt is inclined to attribute these changes to postmortem autolytic processes following the expulsion of the fetus from the uterus. Unfortunately, no reference is made to the condition of the cat's ovaries. The microscopic picture of the tissues of this fetus does not demonstrate that it was retained as a dead body in the uterus long enough to account for the difference in the degrees of development represented by the larger and the smaller fetuses; neither does it afford any evidence to the contrary. Inasmuch as there is no evidence presented in this case which would preclude the probability that the ova which gave rise both to the larger and the smaller fetuses were extruded at the same period of ovulation and were fertilized and implanted approximately at the same time, and inasmuch as we must admit that dead fetuses may be retained in the uterus for relatively long periods without showing advanced retrogressive changes, the conclusion that this is a case either of superfetation or superfecundation does not seem to be warranted.

SUMMARY

Two cases in the cat and one in the dog are described in which fetuses differing markedly in size and degree of development occupied the uterus contemporaneously. In both cases of the cat the condition of the ovaries indicated that the ova which gave rise both to the larger and the smaller fetuses were extruded at the same period of ovulation. The relative positions of the larger and the smaller fetuses in the uterus also precludes the possibility of superfecundation. In the case of the dog, all the embryonic vesicles in the uterus were observed to be approximately of the same size thirty-five days preceding parturition. The tissues of the smaller fetuses in each case show advanced necrotic changes, indicating that these fetuses were retained as dead bodies in the uterus. Inasmuch as dead fetuses may be retained in the uterus for relatively long periods without undergoing extensive autolysis and absorption, it is suggested that in the majority of the cases reported in which fetuses differing markedly in size and degree of development occupied the uterus contemporaneously, the conclusion either that superfetation or superfecundation has occurred is unwarranted.

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Resumen por el autor, Jean Firket
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Sobre el origen de las células germinales de los vertebrados
superiores

En el testículo y ovario del pollo existen dos generaciones de células germinales: las células germinales primarias, que aparecen en estados muy tempranos del desarrollo, antes de formarse la cresta genital, y las células germinales secundarias, que se derivan del llamado "epitelio germinal." Las primeras células pueden transformarse en espermatocitos y ovocitos y aunque degeneran en su mayor parte no es posible determinar si algunas de ellas producen células germinales definitivas, porque en ciertos estados es imposible distinguirlas de esta última clase de células. En el macho de la rata blanca aparecen las mismas dos generaciones, pero las células germinales primarias degeneran antes de alcanzar el periodo de crecimiento y solamente las células germinales secundarias se transforman en las definitivas. La desaparición de las células germinales primarias de los mamíferos durante la ontogénesis en estados mas tempranos del desarrollo que en las aves parece indicar que se las debe considerar como células en "regresión filogenética."

Translation by José F. Nonidez
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ON THE ORIGIN OF GERM CELLS IN HIGHER VERTEBRATES

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The opinion that a continual germinal path exists in all animals and especially in the higher vertebrates is gradually replacing the more conservative idea that germ cells are derived only from Waldeyer's germinal epithelium. Many investigators now hold that, in the early stages of the ontogenesis of any species, cells occur which are absolutely distinct from the soma cells and which are the only cells capable of giving rise to definitive germ cells during the later development. These cells are called primordial germ cells.

Such a continual germinal path, the so-called 'Keimbahn' of German authors, has been described in *Ascaris*, by Boveri; as early as the fifth segmentation division, one is able to recognize one of the blastomeres as being the only progenitor of all future germ cells. It would be certainly valuable, if all animals could be shown to have this development in common.

Many embryologists have accepted this theory for higher vertebrates, but only a few have attempted to prove it; the principal among these are Rubaschkin and Swift. Everyone knows that, in the amniotes, primordial germ cells have been shown to occur in very early stages of ontogenesis before the differentiation of soma cells, and therefore well before the appearance of the genital ridge. The early history of these elements has been carefully studied during the past ten years, but the later history of their evolution, when they are embedded in the genital gland, is not so clearly settled.

Three opinions regarding the later development of these germ cells in higher vertebrates are now defended.

1. Some investigators claim that the primordial germ cells in the genital glands are the only possible germ cells, and that in accordance with this fact the existence of a 'continual germinal path' is a reality (Rubaschkin and Swift).

2. Others believe that the so-called 'primordial germ cells' are really germ cells, but that most of them degenerate and that a second generation of germ cells is derived from the so-called 'germinal epithelium' (Waldeyer) or the sex cords which it produces (Felix, Dustin, Allen, and Firket). These authors call the germ cells belonging to the first generation 'primary germ cells' v.s. to the germ cells derived from the germinal epithelium which are called 'secondary germ cells.'

3. Still others assert that the 'primordial germ cells' are not true germ cells, but are temporary hypertrophied cells which disappear later and that all definitive germ cells are derived directly from the germinal epithelium (de Winiwarter et Saintmont, von Berenberg-Gossler).

During the five years preceding the war, I studied, in the Department of Anatomy of the University of Liege, the changes in primary germ cells during the development of the genital glands in birds. Only one part of this work has been published.¹ The second part dealt chiefly with the development of the chicken's testis. It was entirely written when the war broke out, but because I was on duty in the Belgian army, these last observations could not be published. The Archives de Biologie, printed in Brussels and suspended during the war, will publish my work in 1920.

As regards primary germ cells in the chick, my opinion is as follows:² They are free cells embedded in the mesenchyme tissue of the splanchnopleure and of the radix of the mesentery before the genital ridge appears. In these early stages and in the first days of the developing genital glands, they are migrating cells, and their migration is ensured by their own movements

¹ Recherches sur l'organogenese des glandes sexuelles chez les oiseaux. Ch. I à VI. Arch. de Biol., T. 29, 1914.

² These principal results were published in a preliminary note. Anatomischer Anzeiger, 1914, Bd. 46, S. 422.

until they are embedded and fixed in the sex cords of the genital glands either in the medullary and cortical cords of the ovary or in the sex cords of the testis. Some of them do not reach the sex gland, but they continue their evolution outside of it, becoming oocytes or spermatocytes while still embedded in the mesentery or rete. It seemed to me most important, in order to prove their sexual nature, to observe, outside the genital gland, the transformation of these cells into well-characterized oocytes, for the oocytes observed inside the genital organs can always be said to be elements derived, in situ, from the germinal epithelium or the epithelial derivatives. Most of the primary germ cells in the testis as well as in the ovary subsequently degenerate, and the great majority of the definitive ova or spermatogonia are derived from the epithelial organs of the sex glands and must consequently be called secondary germ cells; nevertheless, there is no reason why certain of the primary germ cells may not produce some of the definitive ova or spermatogonia, as it is impossible, at one stage of the ontogenesis, to distinguish between primary and secondary germ cells.

In addition to the above interpretation of these observations in the chick, the following hypothesis was derived: primary germ cells must be considered to be "*un rappel phylogénique des gonocytes définitifs des classes inférieures notamment des cyclostomes et des Acraniens.*"

Since this work was concluded, other papers on this subject have appeared. Another account dealing with the ovary and the testis of the chick has been written by Swift. Though Swift confirms most of my observations on the organogenesis of the indifferent gonad and ovary, he does not agree with me in regard to the existence of secondary gonocytes. His articles and others, which have been published during the war, will be discussed later in a more complete paper with a fuller review of the literature, where the details of my study on the testis of the albino rat will be given.

Notwithstanding the last articles which conclude that only primordial germ cells form definitive sex cells, the evidence does not seem to me sufficient to establish this opinion. My own

research, started in 1914 on the testis of albino rats, has reinforced my former opinion and brought out a new argument in favor of the hypothesis previously stated regarding the morphological value of the primary germ cells.

Before relating briefly my observations on albino rats, it is a pleasure to acknowledge the kindness of the Department of Anatomy of the Johns Hopkins Medical School and especially that of Doctor Sabin and Doctor Weed for their good welcome and the great opportunity for work which I found in their laboratories.

The material studied consisted of the testis of young albino rats of all stages from birth until seven weeks and also of a few embryonic stages. The organs were fixed in different fixing fluids, particularly those of Flemming, Meves, Regaud, and Bensley (bichromate—osmic—acetic-acid mixture). The three latter were employed for showing the mitochondria (chondriosomes), because Rubaschkin stated that these methods were elective for studying the primary germ cells in other species.³

The structure of the foetal sex cord of the testis has been known for a long time; two kinds of cells have been described—large and small—their nuclei lying regularly in a single row in the peripheral portion of the cord. The larger cells are characterized by their size, their well-outlined cytoplasmic body, and their clear and round nuclei, while the nuclei of the small cells are smaller, more deeply stained, and are oval in shape with their long axes at right angles to the basal membrane.

The occurrence of these two kinds of cells brings up the problem as to whether the larger or the smaller gives rise to the future spermatogonia. This question has become still more interesting since it is evident that the former are not derived from the latter, as is stated in many text-books and even by recent investigators (Hoven), but that the largest cells of the sex cord

³ I have used for this work material belonging to the embryological collections of the Anatomical Department of Liege. First collected by Doctor Duesberg, afterward by Doctor Hoven, and then by myself; I am still enlarging it, due to the kindness of Dr. Milton J. Greenman, of The Wistar Institute in Philadelphia.

of the foetal testis are exactly the same as the so-called 'primordial or primary germ cells' which appear in the early stages of ontogenesis. This has been definitely established by the work of Rubaschkin on mammals and that of Firket and Swift on the chick.

The structure of the sex cord of the albino rat, the first day after birth, is just the same as the typical one described above. The large cells, which we may now call 'primary' germ cells, are easily observed in sections fixed or stained with various histological methods. In these cells a very striking cytological feature may be observed; the mitochondria are grouped in a complete ring surrounding the nuclei, all of them are thick, darkly stained, and very sharply outlined granules; this aspect of the mitochondrial substance differentiates them sharply from the smaller cells (ordinarily called indifferent germinative cells), in which the mitochondria are short undulated filaments. This cytological aspect of mitochondria has been already described in the primordial germ cells of the guinea-pig by Rubaschkin; he attached great importance to this latter feature, because he thought that a granular shape of mitochondria was evidence of the undifferentiated nature of the cells containing them, in contrast with the soma cells in which their filament-shaped mitochondria show their differentiated nature. I have already discussed in a previous paper that interpretation, and have said that I could not accept it; however, it is a valuable cytological method for following these cells in their development.

What is the evolution of these cells in the developing testis of albino rats?

During the days following birth, the gonad increases in size, because of the active multiplication of the small epithelial germinative cells of the sex cord. Among them foci of mitosis take place in which the long axis is most often in a line parallel with the long axis of the sex cord itself. The primary germ cells in this stage do not, or at least very infrequently, divide. This difference in the distribution of the foci of cell division explains the fact that in earlier stages an average of three or four small epithelial cells were found to separate the two nearest primary

germ cells, but that in the five-day-old rats this number has increased to nine or ten. In the following stages, from the fifth to the tenth day, this number increases still more rapidly, according to a new phenomenon of the evolution of the primary germ cells: during the first five days their relative number seemed to decrease because they were not dividing while the sex cords were increasing; after the fifth day their number diminishes absolutely, but not relatively, because they degenerate.

A special type of their degeneration was striking and frequent, characterized by a great hypertrophy of the cells, in which cytoplasm and nucleus seem to be filled with water; the chromatin is shriveled into four or five irregular blocks staining weakly and lying next to the nuclear membrane; the mitochondria lose their sharp outlines and seem to be dissolved in the general cytoplasm. This type of degeneration seems to be a typical one in the evolution of primordial germ cells, as has been shown in the ovary and testis of the chick;⁴ this may be compared to the type of degeneration described by Champy as 'degenerence oviforme.'

In the eighth-day stage, the ratio of the cells in a sex cord is one primary germ cell to eighteen small epithelial cells, while in a rat of ten or eleven days old the primary germ cells become very rare. In this stage there are only a very few cells which may represent the remains of the primary germ cells, they are interspersed in the peripheral portion of the sex cord among the small epithelial cells, from which they are not easily distinguished, although their protoplasm is more deeply stained, their nuclei have a more round shape and seem to contain less chromatin. The number of these cells is so small, two or three in the whole transverse section of the testis, that we may surely conclude that, as regards their relation to future spermatogonia, the primary germ cells have disappeared entirely in the albino rat's testis from the tenth to the fifteenth day after birth.

At that time the first spermatogonia appear; they are easily recognizable by the texture of their nuclei and are very numerous.

⁴ J. Firket, *Recherches sur l'organogenese des glandes sexuelles des oiseaux*. Anat. Anzeiger, Bd. 46, S. 422.

This has been shown very distinctly in the same species by Hoven. Let us insist that these spermatogonia can only be derived from the small epithelial cells, as they are at this stage the only type of cells present in sufficient number in the sex cord. The spermatogonia must then be called 'secondary germ cells.'

It is important to insist that these results have been obtained by studying the sections where the chondriosomes were stained as well as those prepared for the study of nuclear texture. That mitochondria have a very definite granular shape in the first-day stage has been previously noticed; in the later stages, from the tenth to the fifteenth day, no cells containing such mitochondria can be found. All the cells composing the sex cords contain mitochondria which are not deeply stained and which have the shape of short filaments.

The principal conclusion derived in this study of the testes of young rats is as follows: two generations of germ cells exist which can very easily be distinguished from each other because the cells of the second generation (the so-called 'secondary germ cells') only arise when those of the first generation (the so-called 'primary germ cells') have disappeared. This is in interesting contrast with what I have described in the chick, where it is impossible to separate the first from the second generation of germ cells when they are present together.

In general, the primary germ cells in the chick are able to develop at least until the period of growth; some of these having become oocytes and spermatocytes reach the well-characterized stages of preparation for maturation divisions.

This is not true in the albino rat; no primary germ cells ever reach the period of growth, all of them degenerating at an earlier stage.

If we take the chick as the avian type and the rat as the mammalian type, the following conclusion may be drawn: the primary germ cells disappear in the ontogenesis of mammals earlier than they do in the ontogenesis of birds, and can therefore be considered as being cells in a 'phylogenetic regression.'

Let us insist, however, that the lack of function or, at the most, the very low importance of function which the primary germ cells seem to have in amniotes does not diminish the importance of their morphological nature which is asserted by their ancestral character.

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Resumen por la autora, Caroline A. Hosford
Colegio Smith

Nota sobre el esqueleto hiobranquial de *Squalus acanthias*

En el presente trabajo pretende la autora armonizar el conocimiento de la articulación de los hipobranquiales y ceratobranquiales, haciendo algunas correcciones en la literatura mas reciente sobre este punto, mencionando los trabajos de Gegenbaur (1872) y Gibian (1912), que han publicado previamente la relación correcta entre ambas clases de huesos. Esta relación, confirmada en preparaciones hechas por estudiantes durante varios años de prácticas de laboratorio, es la siguiente: *Squalus* posee cinco ceratobranquiales, pero solamente tres hipobranquiales, y los arcos primero y quinto son los incompletos en vez de los cuarto y quinto. El primer ceratobranquial se aplica íntimamente contra la articulación del hipobranquial con el ceratobranquial del segundo arco, pero no está articulado en dicho sitio y posee libertad de movimientos. Del mismo modo las articulaciones de los ceratobranquiales con los hipobranquiales de los arcos tercero y cuarto están cubiertas por el extremo medial del ceratobranquial que les precede. El quinto ceratobranquial no posee hipobranquial, articulándose directamente con la cópula. También describe la autora las articulaciones de los hipobranquiales con los basibranquiales.

Translation by José F. Nonidez
Carnegie Institution of Washington

A NOTE ON THE HYOBRANCHIAL SKELETON OF *SQUALUS ACANTHIAS*

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TWO FIGURES

As in many other laboratories of comparative anatomy, the common dogfish, *Squalus acanthias*, is used at Smith College as one of the types for class dissection, and is thus subjected each year to the careful scrutiny of some fifteen to twenty advanced students of good observational powers.

About 1915, the knowledge of the relations of the hypobranchials to the ceratobranchials was fundamentally changed in the class, as a result of some very careful and accurate work on the part of one of the students. Since then the true relationship has been consistently taught, but so deceptive is the appearance that each class needs to be definitely cautioned in regard to this point. As is well known, there are five ceratobranchials in the visceral skeleton of *Squalus*, but only three hypobranchials. It is the first and the fifth ceratobranchials which lack hypobranchials, not the fourth and fifth as might be supposed from a rather superficial study of their arrangement.

Previous to the time above mentioned, the relationship of this articulation of the cerato- and hypobranchials had been mistaken by the classes in general, leading to the publication of a figure¹ in Doctor Wilder's book, "The History of the Human Body," setting forth the erroneous idea. The figure was made after drawings by students in the course previous to the date of its publication in 1909. It shows the first ceratobranchial articulating directly with a hypobranchial which is called in the

¹ Figure 40.

figure HB_1 . The second and third ceratobranchials each articulate with a hypobranchial, called, respectively, HB_2 and HB_3 . The fourth and fifth ceratobranchials in the figure are without their respective hypobranchials. I may add that Doctor Wilder, whose assistant I am, has long since recognized the error in this figure and that we use it each year as a test for the accuracy of the students' work, encouraging them to correct it by their own dissections.

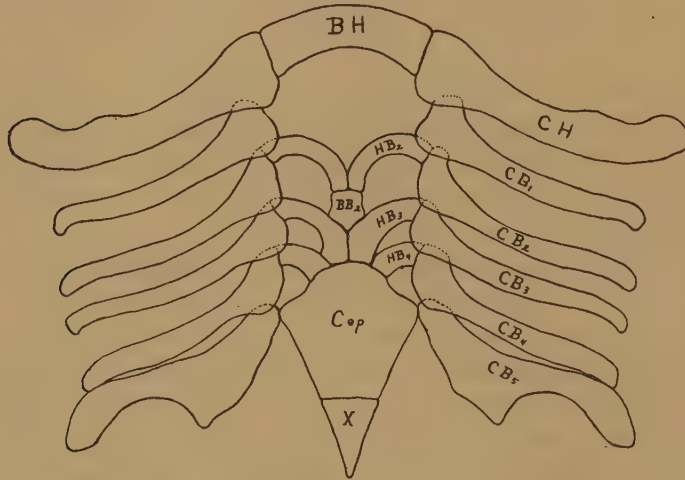


Fig. 1 Ventral view of the hyobranchial skeleton of *Squalus acanthias*, in the natural position. BH , basihyal; CH , ceratohyal; BB_2 , basibranchial of the second branchial arch; HB_{2-4} , hypobranchials of the second to the fourth branchial arches; CB_{1-5} , ceratobranchials; Cop , copula; X , extra piece of copula. $\times 1$.

Recently, however, a paper has been published by Miss Wells ('17)² under Doctor Kingsley's direction, repeating this error, and this has given us the impulse to make the correction which we believe may be prevalent in other laboratories of comparative anatomy. This does not pretend to be a new discovery, however. Gegenbauer ('72)³ and more recently Gibian

² Journal of Morphology, vol. 28, pp. 417-443.

³ Anatomie der Wirbelthiere, p. 422.

(12)⁴ have figures in their publications setting forth the true relationship, Gegenbauer in *Squalus acanthias* and Gibian in *Acanthias blainvillii*. It is rather an attempt to bring the knowledge on this point up to date and to make certain corrections on some of the more recent literature, hoping that it will be of use, since the dogfish is so commonly used in classes of comparative anatomy.

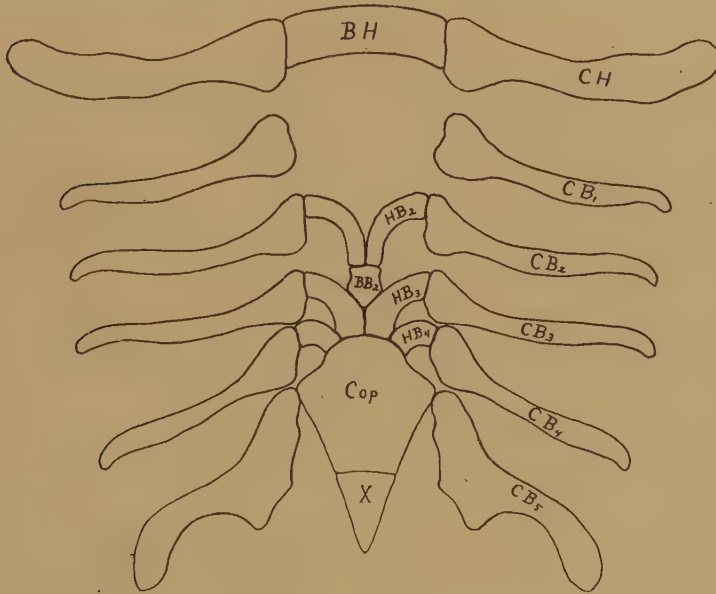


Fig. 2 Same as figure 1 with the parts further separated to show better the correct relationships. Abbreviations as in figure 1.

Miss Wells states that—

the anterior pair of hypobranchials are connected with the first pair of ceratobranchials. Posteriorly they articulate with a median plate of cartilage, the first basibranchial. The second pair of hypobranchials are related in a similar way to the second ceratobranchials and meet each other in the median line, while the first basibranchial is included between their anterior margins. Posteriorly, they abut against the second basibranchial, to be described in a mo-

⁴ Morphologisches Jahrbuch, vol. 45, pp. 57-95.

ment. The third pair of hypobranchials articulate laterally with the third and fourth ceratobranchials, while medially they meet the second hypobranchials on their lateral (posterior) sides, and also they articulate with the second basibranchial. The fifth ceratobranchial is wider than its fellows. . . . This arch lacks a hypobranchial, the ceratobranchial articulating directly with the second basibranchial. The second basibranchial is a flattened triangular plate of cartilage, the apex of the triangle directed posteriorly. At about two-thirds the distance towards the posterior angle, it is slightly constricted, and from this line a shallow groove runs forward in the median line of the dorsal surface.

In reality, as shown in our student preparations, the first ceratobranchial (CB_1) lacks a hypobranchial. The anterior hypobranchial (HB_2) bends around posteriorly at its lateral end, and articulates with the second ceratobranchial, showing that it belongs with this arch and not with the one preceding. The first ceratobranchial is closely applied over this articulation between the cerato- and hypobranchials of the second arch and this is probably the reason for the error. The first ceratobranchial, however, is freely movable, has no articulation at its medial end, and can be easily pushed anteriorly, disclosing beneath, the articulation of the second ceratobranchial and its hypobranchial. The third and fourth ceratobranchials each have their respective hypobranchials, the articulation between them covered in turn by the medial end of the ceratobranchial immediately preceding. The fifth ceratobranchial is without a hypobranchial and articulates with the copula, described below.

The most anterior hypobranchial (HB_2) articulates with a median cartilage, probably the second basibranchial (BB_2), and the third and fourth articulate directly with the large triangular median cartilage which is often called the copula (*Cop.*) (Wells, BB_2). The copula is not only constricted, as Miss Wells suggested, but jointed, being made up of two separate pieces, articulating in the region she described, two-thirds of the distance toward the posterior end.

Just what the copula represents is not known as far as I can tell from the literature, but it is probably a fusion of several of the posterior basibranchials. What has become of the first

basibranchial and of the first and fifth hypobranchials is also not known. I examined two stages of the *Squalus* embryos, but both were like the adult in respect to their hypobranchial apparatus. These two embryos were taken from the bodies of adults and measured 15 and 20 cm., being perhaps about fourteen and seventeen months old. Undoubtedly, the study of a still younger stage would throw some light on the problem.

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Observaciones sobre la atresia folicular en el ovario de la coneja.

Los folículos de tamaño medio y los de gran tamaño experimentan atresia durante todos los estados del ciclo sexual del ovario de la coneja. En este animal no existen cambios cíclicos semejantes a los que tienen lugar en el ovario del conejillo de indias. También existe atresia de los folículos pequeños durante todos los estados del ciclo sexual, sin que haya aparentemente relación definida alguna entre el número de folículos atréticos y el periodo de dicho ciclo. En los folículos de tamaños medio y grande, el proceso inicial de la atresia consiste en la degeneración de la granulosa. En los folículos pequeños los primeros cambios afectan al óvulo y a la granulosa, siendo mas pronunciados en el primero que en esta última. Mientras que el óvulo así afectado degenera completamente y es absorbido, la granulosa sana en la mayor parte de los casos sin presentar, sin embargo, ningún vestigio de proliferación. En algunos casos la granulosa afectada de atresia puede ser invadida por el tejido conjuntivo, completándose la atresia de este modo. Células de la granulosa a menudo emigran, llegando hasta penetrar en el interior del óvulo normal; en este caso dichas células se convierten en elementos necróticos y desaparecen, dejando en el citoplasma ovular gránulos débilmente teñidos.

Translation by José F. Nonidez
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OBSERVATIONS ON THE FOLLICULAR ATRESIA IN THE RABBIT OVARY

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SEVEN FIGURES

The work of Waldeyer,¹ Henneguy,² and others³ has shown that there exist in the ovaries of the mammalian and other vertebrates processes of retrogression by which the greater proportion of the ova and Graafian follicles degenerate and disappear, leaving a comparatively small number of follicles to attain maturity.

In the human ovary, Stevens,⁴ in 1904, pointed out that during the premenstrual life the Graafian follicles that have reached a certain size may disappear by atresia.

In 1911, Leo Loeb⁵ established in the ovaries of the guinea-pig the occurrence of certain cyclic changes corresponding to the cyclic changes taking place in the uterine mucosa. He⁶ has brought to light the fact that, not as a direct effect of ovulation itself, but consequent to or accompanying the conditions leading to ovulation, the membrana granulosa of all the large or medium follicles rapidly degenerate; the degeneration, however, not depending upon any local effect produced by ovulation, since the phenomenon occurs in both ovaries even if the rupture of the follicles should take place only in one.

The process of atresia of the large or medium follicles as observed by Loeb in the guinea-pig consists of a primary degeneration and dissolution of the cells composing the membrana granulosa, followed by organization of the follicular cavity by the connective-tissue cells of the theca growing into the space formerly lined by the membrana granulosa. By this process practically all these follicles are eliminated.

About ten days after the ovulation the newly formed medium-sized and large follicles begin again to degenerate, while smaller follicles continue to grow to large or medium size. This period following the first ten days is called by Loeb the period of follicular equilibrium. A few follicles undergo a further development to full maturity which makes them ready for the next ovulation. In case a pregnancy follows this ovulation, the changes that take place in the ovary are essentially the same, except that the period of the sexual cycle or the period between the two successive ovulations is prolonged, and this prolongation persists throughout the entire gestation. He further demonstrated that the prolongation of the sexual cycle thus observed during pregnancy can be prevented by an extirpation of corpora lutea. He, therefore, concludes that the corpora lutea are responsible for the absence of ovulation during pregnancy. Previously he⁷ has determined that the corpus luteum does not prevent the ripening of the follicles, but merely the rupture of the ripe follicles.

In 1914, the same author⁸ determined that the proportion of the ovarian follicles which are in the late stages of connective-tissue atresia to those in the stage of the granulosa degeneration shows two maxima, one about six or seven days after ovulation and another at the time preceding the next ovulation.

These observations were chiefly confined to the process of atresia of the large or medium follicles and its cyclic variations.

In the rabbit ovary, Loeb⁹ has observed that the small as well as large or medium follicles degenerate and that whereas in the large or medium follicles the degeneration of the granulosa is primary, in the small follicles the first degenerative change occurs in the ova. Heape¹⁰ has also observed that the small follicles degenerate in the rabbit ovaries, but has not described the atretic process in any degree of detail.

In 1916, Loeb¹¹ further pointed out that in the rabbit ovary cyclic changes in the follicular apparatus comparative to those observed in the guinea-pig do not occur. A thorough quantitative determination, however, has not been made by this author.

Stevens has described in the premenstrual human ovary a primary destruction of the ovum by granulosa cells which immigrate into the ovum. It is of interest to determine whether a similar process occurs in the ovary of the rabbit.

For these reasons it has become of interest to carry out an investigation concerning follicular atresia in the rabbit, and in particular study:

1. The conditions of the rabbit ovaries at various periods of the sexual cycle;
2. Differences in the atretic process of the large and medium follicles and of the small follicles;
3. The frequency of the degeneration of small follicles at the different stages of the sexual cycle, and
4. The fate of foreign cells that enter the ovum of the rabbit.

The author takes this opportunity to express his indebtedness to Professor Leo Loeb for the suggestion of the problem and the guidance throughout the study.

MATERIALS AND METHOD OF STUDY

Ovaries of twenty-nine rabbits which had been fixed in Zenker's fluid, cut into serial sections, and stained with haematoxylin and eosin were studied through all sections in series.

The ovaries of the following rabbits were used: 1) Rabbit 8 weeks old; 2) rabbit 16 weeks old; 3) adult resting stage; 4) $7\frac{1}{2}$ days after copulation with male sterilized by ligating the vas deferens; 5) 35 minutes after copulation; 6) 3 hours after copulation; 7) 10 hours after copulation; 8) 18 hours after copulation; 9) 19 hours and 20 minutes after copulation; 10) 2 days after copulation; 11) 5 days after copulation (two rabbits); 12) 5 days and $15\frac{1}{2}$ hours after copulation; 13) 6 days and 17 hours after copulation; 14) $7\frac{1}{2}$ days after copulation; 15) 7 days and 20 hours after copulation; 16) 8 days after copulation; 17) 10 days after copulation (three rabbits); 18) 10 days and $17\frac{1}{2}$ hours after copulation; 19) 11 days after copulation (two rabbits); 20) 12 days after copulation; 21) 14 days

and 13 hours after copulation; 22) 16 days after copulation; 23) 14 to 17 days after copulation; 24) 17 days after copulation; 25) 20 days after copulation; 26) 24 days after copulation.

1. CONDITIONS OF OVARIES AT DIFFERENT PERIODS OF THE SEXUAL CYCLE

At various stages in the sexual cycle the conditions of the ovaries are as follows:

Ovaries of the rabbit eight weeks old. Ovaries are small, containing some healthy medium-sized follicles. No large follicles are noted. The number of small developing follicles is very large. Only one small follicle is seen in the process of atresia. Some ten medium-sized follicles show degeneration of the granulosa and connective-tissue atresia. There is no interstitial gland present at this stage.

Ten weeks old. Ovaries show some fairly large follicles. No interstitial gland is as yet presented. Practically the entire organ is occupied by primordial and small developing follicles. In all, six small follicles show atresia. Otherwise the conditions found are similar to those in the first ovary.

Sixteen weeks old. Ovaries show many large and medium-sized follicles, some of which show degeneration of the granulosa and a few others show connective-tissue atresia. Foci of interstitial-gland tissue are numerous. Only two small atretic follicles are seen.

Adult resting stage. Ovaries contain numerous areas of interstitial-gland tissues. Several large follicles are noticed. The number of healthy medium follicles is fairly large. Many medium follicles show degeneration of the granulosa and connective-tissue atresia. Small atretic follicles number ten in all. The total number of primordial and small developing follicles is not very large, due to a relative thinness of the cortex.

Seven days after copulation with sterilized male. Ovary is of a moderate size, showing several corpora lutea with central cavities filled with blood. Several large follicles are healthy. Many medium-sized follicles are atretic. The total number of small atretic follicles is nine.

Thirty-five minutes after copulation. There are three fully developed follicles protruding into the free surface of the ovary pushing before them the tunica albuginea, evidently ready to rupture. Numerous healthy medium and several healthy large follicles are noted. Many medium-sized follicles show granulosa degeneration and as many show connective-tissue atresia. Some of the large follicles also show degeneration of the granulosa. The greater parts of the ovary are occupied by interstitial gland and the cortex is relatively thin. The total number of small atretic follicles reaches nineteen.

Three hours after copulation. Ovaries are extremely small and the total number of slides is only twenty-five. Three fully developed follicles are noted, not yet ruptured. Some medium-sized follicles show granulosa degeneration, and a few additional ones show connective-tissue ingrowth. A few large follicles are in various stages of granulosa degeneration. There are many medium-sized follicles in a healthy state, and there is a moderate number of small healthy follicles. Only four small atretic follicles are noted, but this should probably be considered a moderate number, judging from the relative scarcity of small follicles in the ovary.

Ten hours after copulation. Ovaries are large, composed chiefly of interstitial gland. A relatively small number of follicles occupy the cortex. In all, about six ripe follicles are seen about ready to rupture. Only a few large and medium-sized follicles are atretic. The small atretic follicles number eleven in all. Blood-vessels are generally congested.

Eighteen hours after copulation. The ovary is of a moderate size, containing numerous follicles in all stages of development. Three follicles have recently ruptured. Their walls are made up of lutein cells, and the cavities are filled with serum and blood-corpuscles. The openings left by the rupture are small, granulosa and lutein cells closing in on either side of the openings. A majority of large or medium follicles show degeneration of the granulosa and in some instances of ova. Medium-sized follicles in connective-tissue atresia are quite numerous. Several medium-sized follicles appear to be healthy. The total number of small atretic follicles reaches twenty-six.

Nineteen hours after copulation. About six follicles have ruptured, the opening in each case being practically closed by new lutein cells. The cavities of the follicles are filled with blood and walls composed of lutein cells. Several large follicles are normal. Not many medium-sized follicles are atretic. Numerous primordial and small follicles appear normal. Thirty-three small atretic follicles are encountered.

Two days after copulation. The ovaries are large, showing six recently ruptured follicles with cavities much narrowed by corpus-luteum tissue. A large healthy follicle is encountered. Most of the medium-sized follicles are healthy, only a few showing atresia. The number of small atretic follicles is seven. As the set of serial sections is not complete, this number is not of much significance.

Five days after copulation. In the first animal the ovary is large. Recent corpora lutea contain central cavities filled with blood. There are many healthy medium follicles and numerous healthy small follicles. A moderate number of medium follicles show various stages of atresia. In the second animal, the ovary is of a moderate size. Several corpora lutea are found in about the same condition as in the first animal. Many healthy small and medium follicles are seen. The total number of small atretic follicles is twelve.

Five days and fifteen and a half hours after copulation. Ovaries are of moderate size. Several corpora lutea still contain central cavities filled with blood. Some large normal follicles are noted. Many medium as well as small follicles are found normal. A small number of medium follicles show various stages of atretic changes. The total number of small atretic follicles is seventeen.

Six days after copulation. Ovaries are of a moderate size, showing several corpora lutea still with central cavities. Occasional large follicles are found normal. Many medium-sized follicles show connective-tissue atresia, and less frequently granulosa degeneration. The number of small atretic follicles totals seven.

Seven days and twenty hours after copulation. Ovaries are moderate in size and show corpora lutea with central cavities much reduced in size. Several almost fully developed follicles are seen. Several medium follicles are atretic and about the same number are healthy. The small atretic follicles number seventeen.

Eight days after copulation. Ovaries are of a moderate size, showing corpora lutea with central cavities almost closed except for a small space filled with fibrinous material. Some large follicles are seen to be healthy. Several of these show granulosa degeneration. Several medium-sized follicles are in the terminal stages of atresia. Quite a large number of small healthy follicles are noted. The number of small atretic follicles is small, only four being found.

Ten days after copulation. In the first animal the ovaries are of moderate size, showing several corpora lutea with small central cavities. Numerous small follicles are normal. Several large follicles are also normal. Quite a large number of small healthy follicles are noted. The number of small atretic follicles is eight. In the second animal all corpora lutea except one show obliteration of the central cavities. Several large and also medium follicles are healthy. Medium follicles in moderate number show both granulosa degeneration and connective-tissue atresia. The number of small atretic follicles totals nine. In the third animal several corpora lutea still contain small central cavities filled with fibrinous material. A few almost fully developed follicles appear normal. Some large follicles show granulosa degeneration. A moderate number of medium follicles in granulosa degeneration and connective-tissue atresia are noted. Small healthy follicles are quite numerous. The total number of small atretic follicles is seven.

Ten days and seventeen and a half hours after copulation. Some of the corpora lutea still contain small cavities filled with fibrinous material, others have lost all trace of cavities. A few well-developed follicles are healthy. Several large follicles show granulosa degeneration. A moderate number of medium-sized follicles are in various stages of atresia. Numerous small and

primordial follicles are healthy. The total number of small atretic follicles is twenty-four.

Eleven days after copulation. Only one of the corpora lutea shows a small cavity. A few almost fully developed follicles are healthy. Some of the large follicles show granulosa degeneration. Many medium-sized follicles present various stages of atresia, other medium-sized follicles equally numerous appear healthy. The total number of small atretic follicles is ten.

Twelve days after copulation. Corpora lutea are completely developed. Several large healthy follicles and others with granulosa degeneration are found. Many medium-sized follicles show various stages of atresia. Normal medium follicles are equally numerous. The total number of small atretic follicles is fourteen.

Fourteen days and thirteen hours after copulation. Some corpora lutea still contain traces of cavities filled with fibrinous material. Several almost fully developed follicles are healthy, several others show granulosa degeneration. Numerous medium-sized follicles show granulosa degeneration and connective-tissue atresia. The total number of small atretic follicles is fifteen.

Sixteen days after copulation. Several corpora lutea are in the same stage as in the preceding ovary. Some almost ripe follicles are healthy, a few others show granulosa degeneration. A moderate number of medium-sized follicles show various stages of atresia. The total number of small atretic follicles is three.

Fourteen to seventeen days after copulation. Several well-formed corpora lutea are seen, only one of which containing a small cavity. A few almost ripe follicles are healthy, a few others show granulosa degeneration. Quite numerous medium-sized follicles show various stages of atresia. The number of small atretic follicles is six.

Seventeen days after copulation. Ovaries are very small and the cortex is thin, containing relatively few follicles. Corpora lutea are fully developed. No fully developed follicles are seen. Many medium-sized follicles are in various stages of atresia. A fairly large number of primordial and small follicles appear healthy. The total number of small atretic follicles is one.

Twenty days after copulation. Corpora lutea show no cavity. A few large follicles appear normal. A few medium-sized follicles show granulosa degeneration and some connective-tissue atresia. There are some but not many healthy follicles of medium size. A moderate number of primordial and small developing follicles are found. The total number of small atretic follicles is five.

Twenty-four days after copulation. A few large follicles are healthy, a few medium-sized follicles atretic. Several medium-sized follicles show terminal stages of the atretic process. Healthy primordial and small follicles are seen in rather a small number. The total number of small atretic follicles is five.

From the above descriptions it will be seen that the ovulation occurs in the rabbit some time between ten and eighteen hours after copulation, and that it is independent of fecundity of the male. Corpora lutea of pregnancy are completely formed in the rabbit between twelve and seventeen days after the copulation.

At various stages of sexual cycle, follicles of different sizes are found both atretic and healthy. Furthermore, the proportion of the follicles showing connective-tissue atresia to those with granulosa degeneration does not present any definite cyclic variation. Thus, at the time of ovulation, for example, eighteen hours after copulation, there are healthy medium-sized follicles as well as atretic follicles of the same size. Of the atretic follicles, those in granulosa degeneration and the connective-tissue atresia are about equal in number. Ten days after the copulation, the condition of the follicular apparatus is essentially similar to that found eighteen hours after copulation. In the rabbit ovary, therefore, the ovulation does not seem to be followed by a total disappearance of large and medium follicles. It is further noteworthy that in the rabbit ovary there is no cyclic variation in the proportion of the follicles in the connective-tissue atresia to those with granulosa degeneration. These findings are, therefore, quite different from those observed in the guinea-pig by Loeb.

2. DIFFERENCES BETWEEN THE ATRETIC PROCESS IN THE LARGE AND MEDIUM FOLLICLES AND IN THE SMALL FOLLICLES

In the large and medium follicles the first degenerative changes occur in the membrana granulosa. These changes consist of a fatty degeneration of the cytoplasm and a pyknosis and karyorrhexis of the nucleus of the cells composing the innermost layer of the granulosa. These changes soon involve the cells of the outer layers and also those constituting the discus proligerus. Such changes are followed by a beginning migration into the granulosa of the connective-tissue cells and capillaries of the theca interna. By this time the ovum begins to show certain alterations in its appearance. The zona pellucida appears denser than normal; the cytoplasm of the ovum stains more deeply with eosin; and the nucleus becomes pyknotic and soon disappears.

The organization of the space occupied by the degenerating granulosa and the follicular cavity, which follows the ingrowth of the connective-tissue cells and capillaries, advances progressively, while evidence of progressive degeneration of the ovum does not appear until the organization of the granulosa has progressed considerably further. Thus, with the granulosa practically replaced by the connective tissue and the size of the follicular cavity considerably diminished, the ovum still remains visible with its deeply eosin-staining cytoplasm within the dense zona pellucida. With a progressive increase in the connective tissue, the follicle gradually contracts until the picture presented is that of a thick wall of connective tissue surrounding a dense zona pellucida enveloping the egg which stains deeply red. Still later, the cytoplasm of the egg disappears and the distorted zona alone remains enclosed by the connective-tissue wall. The final disappearance of the follicle is effected by a complete absorption of the remnant of the zona and a contraction of the fibrous tissue. In connection with these changes an evidence of phagocytosis of the ovum by foreign cells has not been obtained.

Small follicles, which contain a single layer of granulosa cells and vary from twice to six or seven times the size of a primordial follicle, undergo atresia quite frequently in the rabbit ovary.

Here, the first noticeable changes appear both in the ovum and the granulosa. The nucleus of the ovum becomes hyaline and irregular, and the granules of the cytoplasm appears definitely coarser than normal. The zona pellucida is dense and more or less distorted in its outline. Between the zona and the cytoplasm of the ovum there is a clear space of varying thickness. The membrana granulosa is intact and is irregularly single layered at some points and double layered elsewhere. The nuclei of the granulosa cells are more closely packed together and appear distinctly denser than normal, while their cytoplasm appears diminished, as indicated by a decrease in the distance between the neighboring nuclei and in the height of the cell body.

The next and the most frequently observed changes are an invasion of the interior of the zona pellucida by granulosa and connective-tissue cells. The membrana granulosa appears practically normal. The zona pellucida is dense and distorted. The space lined by the zona is occupied by variable numbers of cells, some of which resemble granulosa cells and others connective-tissue cells. These two types of cells may be seen in the process of penetrating the zona pellucida.

In the accompanying figure one of the cells of the membrana granulosa has left its neighbors and, exerting pressure on the zona, is about to enter the cavity formerly occupied by the egg. Closely behind it a cell with a fusiform nucleus, resembling the connective-tissue cell of the theca interna, is apparently pointing in the same direction. In the interior of the zona pellucida there are found quite a large number of cells of both types which have already immigrated from without. In the granulosa cells of these atretic follicles mitotic figures have not been found.

In other instances, much less frequently observed than the above, the granulosa cells are irregularly arranged, their nuclei considerably shrunken and closely packed together, and the cytoplasm entirely clear. In a follicle of this kind, shown in the figure 3, these cells have detached themselves from the rest of the granulosa and appear to be approaching the zona. The latter is decidedly condensed and distorted, and surrounds the coarsely granular remnant of the cytoplasm of the ovum. The nucleus

of the egg itself cannot be found. Among this mass of granular material are seen three distinct cells. These cells possess markedly swollen cytoplasm which is loaded with the same coarsely granular material as that lying outside of the cells. The nuclei

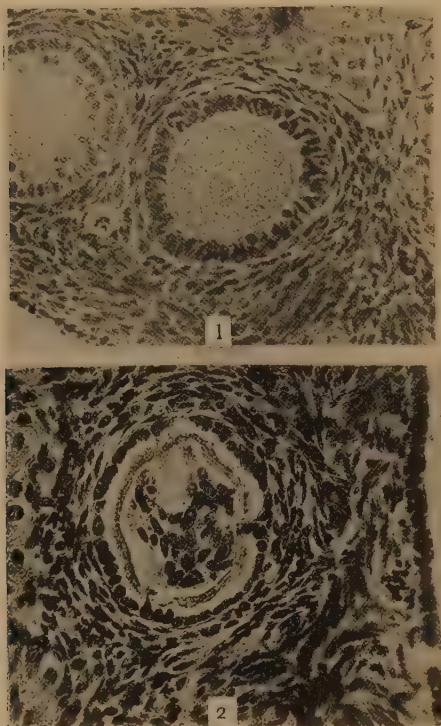


Fig. 1 Shows a hyaline nucleus, surrounded by coarse, granular cytoplasm. Note the appearance of the granulosa in contrast to that shown by the neighboring follicle. $\times 266$.

Fig. 2 The granulosa is practically normal. The zona is dense, and contains in its interior numerous cells. Note one of the granulosa cells penetrating the zona, and a theca cell following closely behind it. $\times 266$.

of these cells are well preserved and appear to be surrounded by the swollen cytoplasm above described.

In still other instances, encountered only slightly more frequently than the above, pictures are obtained which probably represent stages following those reproduced in figure 3 and just

described. The site of the original membrana granulosa is now occupied chiefly by connective-tissue cells irregularly arranged. Among these and theca cells surrounding them are found a small number of lymphocytes. The zona pellucida is still present, but

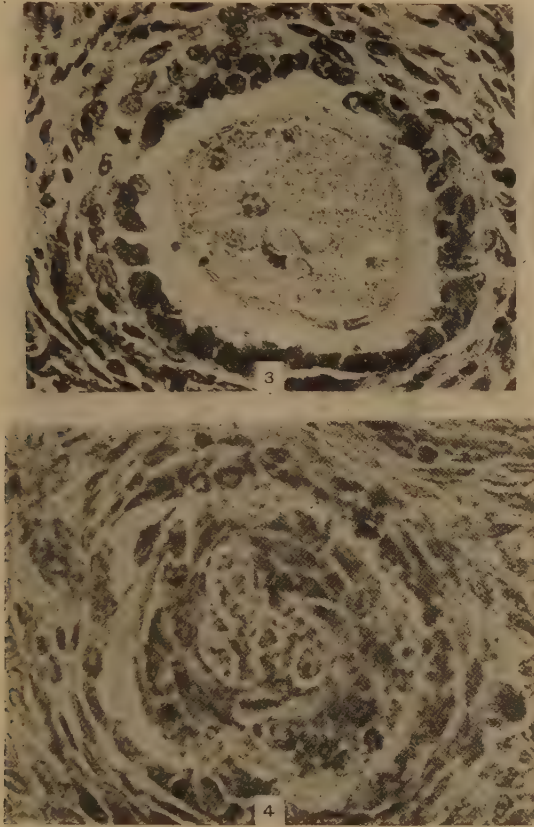


Fig. 3 $\times 552$. Fig. 4 $\times 552$

is definitely stretched and thinned by the pressure from within. The zona encloses a material which consists of coarse granules of the size of a granulosa cell and slightly stained by haematoxylin and eosin so that they appear grayish brown. These coarse, spherical granules are surrounded by a clearer area stained faintly with eosin and also spherical in shape. Between this

mass and the zona pellucida there are numerous cells in a good state of preservation and containing an elongated, almost fusiform, nucleus. Some of these nuclei have assumed a crescentic shape as a result of pressure exerted by the granular substance above described; it is probable that these cells have ingested the coarse, granular material which, judging from its size and appearance, may represent degenerated granulosa cells or remnants of the egg (fig. 4).

Thus, in the large and medium-sized follicles, the atretic process consists of a primary degeneration of the granulosa cells. Degenerative changes in the ovum appear later. The organization of the degenerating granulosa by connective tissue is completed before the ovum entirely disappears. The disappearance of the zona pellucida and the contraction of the organizing connective tissue constitute the end of the atretic process.

In this connection, Stevens' observations on the human ovaries might be briefly mentioned for the sake of comparison. This author states that the membrana granulosa degenerates on account of the lack of nutrition incident to its detachment from the theca interna. Some of these granulosa cells, according to Stevens, invade the ovum through an opening which they make in the zona and phagocytose the ovum.

Loeb, in his work on the guinea-pig ovaries, has made a statement that the inner layer of the granulosa becomes necrotic, followed by similar changes in the outer layers. As soon as the theca interna is exposed, there begins an invasion of the area of degeneration by the connective-tissue cells, and the disintegrating granulosa cells are often taken up by phagocytes. He has also observed that coincident with various stages of atresia nuclear divisions may occur in the ovum. By the time the connective-tissue ingrowth has progressed to a stage of fairly well-established organization, the ovum is seen to have disappeared, leaving a swollen and distorted zona pellucida which is encircled by the connective-tissue wall.

Evidently the degeneration of the membrana granulosa deprives the ovum of its nutrition and thereby brings about its necrosis. Phagocytosis of the previously healthy ovum by granulosa cells as described by Stevens in the human ovary does

not seem to occur in the rabbit, neither do we observe in the ovum of the rabbit the progressive changes which occur in the guinea-pig. That the granulosa degeneration precedes the onset of similar changes in the ovum of the large or medium follicle and that the former is completed long before the latter appear certain from the studies of Loeb and of the present author.

In the case of the small follicle, the sequence of events in atresia is different from that found in the medium and large follicles, inasmuch as the first changes appear simultaneously in the egg, granulosa, and zona pellucida, whereas in the large or medium follicles the first changes occur in the granulosa and the egg is affected relatively late in the process of atresia. Moreover, it seems that, while the ovum after it has once begun to degenerate continues in this process until it is completely disintegrated, the granulosa is able to recover in many instances. I am inclined to interpret in this way the fact that in many cases remnants of follicle are found in which the granulosa appears healthy, but in which the egg has been entirely destroyed. It is probable that in such instances a recovery of the granulosa takes place after the egg has been resorbed. The egg seems to be lost in each of these instances after the degenerative changes in the nucleus and cytoplasm (coagulation of the cytoplasm into coarse granules and condensation of the zona pellucida) have set in.

In some cases, however, the granulosa cells which have suffered certain degenerative changes as described above, instead of recovering, seem to continue to degenerate further; while some of them invade the ovum and phagocytose the detritus of its cytoplasm, the majority of them seem to disintegrate and to be substituted by the connective tissue of the theca. This is the interpretation which the present author is inclined to give to such pictures as that represented by figure 4.

It appears probable, then, that whereas the ovum degenerates in every case, the granulosa is usually only slightly affected and recovers in most instances, and that in certain cases, however, it may fail to recover, and it perishes with the egg and is substituted by connective tissue. While it is impossible to be certain in regard to the sequence of events in the atresia of the small follicle, the view presented here seems to be the inter-

pretation which fits in best with the facts that have been described.

Heape has stated that small atretic follicles are situated in the neighborhood of large developing follicles which thus deprive them of their nutrition. My observations, on the contrary, shows that the location of the small degenerating follicles is by no means confined to the neighborhood of large growing follicles, but that these follicles may be located at a considerable distance from the developing follicles as well as near them. Moreover, one small follicle may be seen in atresia while several others of the same size and of similar location may be entirely healthy. The situation of these small atretic follicles, therefore, cannot explain the cause of the degeneration. What the primary cause of these degenerative changes in the follicle may be constitutes an interesting question which remains still unanswered.

3. THE FREQUENCY OF DEGENERATION OF SMALL FOLLICLES AT DIFFERENT STAGES OF THE SEXUAL CYCLE

From the descriptions given under the heading of "The Conditions of Ovaries at Different Stages of Sexual Cycle" it will be seen that no definite variation exists in the frequency of the atresia of large and medium follicles in the rabbit ovary. In the ovaries rich in follicles of varying sizes the number of large and medium atretic follicles is correspondingly large, whereas in those ovaries in which the follicles are scant atretic follicles are, in general, small in number.

In the case of small follicles, practically the same relationship exists. A slight variation in the actual number of small atretic follicles does occur from one stage to another, but without any definite relation to the length of time which has elapsed since the last ovulation. In the case of small follicles, also, the larger the total number of follicles in the ovary in general, the more frequently are seen follicles in the process of atresia. From sixteen days on following the copulation, the incidence of atresia of small follicles appears to have decreased in the present series, but this observation again does not prove any cyclic variation, since in these stages the ovaries examined show a comparatively smaller total number of follicles.

In counting the small follicles which have become atretic, one has to keep in mind the possibility that in the later stages of atresia follicles may perhaps persist for a long period of time. For this reason it is impossible to obtain a definite knowledge as to the time the atretic process began.

The following table represents results of a quantitative determination of the frequency of atresia of small follicles at various stages of sexual cycle. Approximate sizes of ovaries representing these stages and approximate number of follicles of varying sizes are also presented in order to substantiate the opinion I have advanced above.

AGE OF THE RABBIT; STAGE OF SEXUAL CYCLE	APPROXIMATE SIZE OF OVARIES	APPROXIMATE NUMBER OF FOLLICLES OF ALL SIZES	TOTAL NUMBER OF SMALL ATRETIC FOLLICLES
6 weeks old.....	Small	Abundant	1
10 weeks old.....	Slightly larger	Abundant	6
16 weeks old.....	Medium	Abundant	2
Adult resting stage.....	Large	Moderate	10
7½ days after sterile copulation.....	Large	Fairly abundant	9
35 minutes after copulation.....	Large	Fairly abundant	19
3 hours after copulation.....	Small	Moderate	4
10 hours after copulation.....	Large	Moderate	10
18 hours after copulation.....	Large	Fairly abundant	26
19 hours after copulation.....	Large	Fairly abundant	33
2 days after copulation.....	Large	Moderate	7
5 days after copulation.....	Large	Moderate	16
5 days after copulation.....	Large	Moderate	12
5 days 15 hours after copulation....	Large	Moderate	17
6 days after copulation.....	Large	Scant	7
7 days after copulation.....	Large	Moderate	17
8 days after copulation.....	Large	Scant	4
10 days after copulation.....	Large	Moderate	8
10 days after copulation.....	Large	Moderate	9
10 days after copulation.....	Large	Moderate	11
10 days 17½ hours after copulation..	Large	Fairly abundant	24
11 days after copulation.....	Large	Moderate	10
12 days after copulation.....	Large	Moderate	14
14 days and 13 hours after copulation.	Large	Moderate	15
16 days after copulation.....	Small	Fairly abundant	3
14 to 17 days after copulation.....	Large	Rather scant	6
17 days after copulation.....	Small	Rather scant	1
20 days after copulation.....	Large	Rather scant	5
24 days after copulation.....	Medium	Rather scant	5

4. THE FATE OF THE FOREIGN CELLS WHICH ENTER THE HEALTHY OVUM

In discussing the atretic process I have stated that the phagocytosis of the previously healthy ovum by invading cells, such as Stevens believes to take place in the human ovary, does not occur in the rabbit. Yet, even in the rabbit it is easy to observe the entrance of granulosa cells into the cytoplasm of the ovum, and this is a very frequent occurrence. The question arises whether or not these cells are factors in bringing about the degeneration of the ovum, in accordance with the view advanced by Stevens in the case of the human ovary. For this reason a careful examination of numerous follicles, the ova of which contained these cells, has been made.

Cells can be seen to migrate from the inner margin of the membrana granulosa and to encroach upon the outer surface of the zona pellucida. Some of these cells evidently penetrate the zona without, however, leaving any detectable break in its continuity, and lie close to the inner surface of the zona. Such cells may still appear normal, and even their cytoplasm may be well visible. Usually, however, the nucleus appears slightly irregular as soon as the cell has entered the interior of the zona (figs. 5 and 6). In other ova a small number of nuclei of the invading cells are found in various stages of degeneration. The nuclear membrane has disappeared entirely, and thus nuclei present a decidedly irregular outline. Some of these irregular nuclei have lost a greater part of their staining power, and appear merely as faintly stained dots in the cytoplasm of the ovum (fig. 7). In all these instances, in which the nuclei of the invading cells are seen in various stages of degeneration, the ova themselves appear perfectly normal.

The only inference that can be drawn from such findings is that the cells which invade the healthy ovum, instead of causing a degeneration of the egg, themselves undergo degeneration and soon disappear. Since such findings are constant and have been met with in numerous instances, the rôle of phagocytosis cannot be attributed to these cells so far as the healthy ovum is concerned.

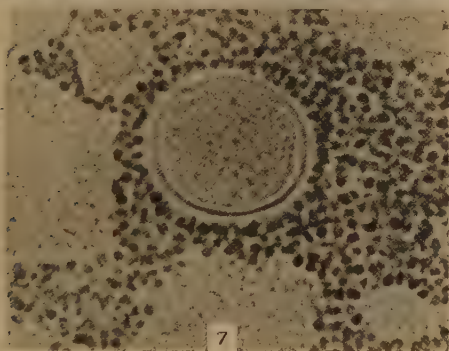
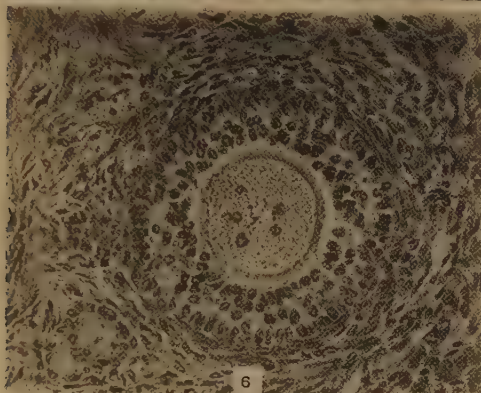
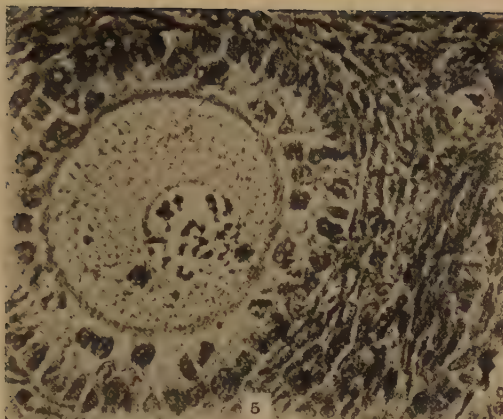


Fig. 5 The ovum is healthy, the granulosa normal. Along the outer border of the zona are several granulosa cells which have migrated from their neighbors; some of these cells encroach upon the zona. Two have already entered the ovum. $\times 552$.

Fig. 6 One of the granulosa cells is encroaching upon the zona. Six cells are seen in the ovum; one of these which lies close to the nucleus of the egg is degenerating. $\times 266$.

Fig. 7 The ovum surrounded by discus proligerus contains several faintly stained dots which represent the last traces of the granulosa cells that have invaded the ovum. $\times 266$.

In contrast to the above observations, it seems certain, as has been previously noted, that when granulosa cells invade the ovum after it has undergone a certain degree of degenerative changes, the invading cells may not only remain healthy for a certain period of time, but may further assume the rôle of phagocytes and probably contribute to the destruction of the products of degeneration.

SUMMARY AND CONCLUSIONS

1. Follicles of medium and large size undergo atresia at all stages of the sexual cycle; likewise well-preserved follicles of various sizes may be seen at all stages of the sexual cycle. There is no indication that there exists a noticeable difference in the proportion between healthy and atretic follicles at the time of ovulation or soon after and in later stages of the sexual cycle. Cyclic changes such as they occur in the ovary of the guinea-pig do not take place in the rabbit.

2. In addition to the atresia of medium and large follicles, small follicles can be seen to degenerate in the ovary of the rabbit. Degenerating small follicles can likewise be seen in all stages of the sexual cycle, there being apparently no connection between the number of atretic follicles and the stage of the sexual cycle.

3. In contradistinction to the atresia of medium and large follicles where the degeneration of the granulosa is the primary factor, in the early stages of the atresia of small follicles changes can be seen in the egg as well as in the granulosa; but the changes in the egg are much more pronounced than those in the granulosa. It is probable that while the egg degenerates and is absorbed, the granulosa can recover in most cases and persist for a considerable period of time, without, however, showing any signs of proliferation. Proliferation of the granulosa and indirectly of the ovary probably depends, as Loeb¹² and Walsh¹³ have suggested, on an internal secretion of the ovum which acts as a growth stimulus.

In some cases, however, the granulosa of atretic small follicles can be seen to become invaded by the connective tissue of the theca and thus the atresia to become complete.

4. Cells, probably of granulosa origin, can be seen to immigrate into the normal egg at all stages of the sexual cycle and in large, medium, and small follicles. These cells usually undergo a rapid disintegration within the substance of the ovum. These cells do not act as phagocytes as long as the egg is healthy, but they may perhaps do so in case the egg degenerates; only in degenerating eggs of small follicles does one find evidences of phagocytosis.

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Resumen por el autor, O. Larsell,
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Vejigas pancreáticas

El autor describe un caso de vejiga pancreática que presenta una disposición de sus conductos algo diferente de la descrita en otras vejigas pancreáticas. También analiza los casos de este género hallados en la literatura, los cuales son trece, incluyendo el presente, intentando disponerlos en serie fundándose en la relación de sus conductos con el conducto pancreático y sus ramas primarias y en su probable derivación embrionaria. Parece sumamente probable que las vejigas pancreáticas sean desarrollos anómalos de uno de los lóbulos pares del páncreas ventral embrionario.

Translation by José F. Nonidez
Carnegie Institution of Washington

PANCREATIC BLADDERS

O. LARSELL

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TWO FIGURES

Since 1815, when Mayer described a case of pancreatic bladder in the domestic cat, eight additional instances have been recorded. Gage ('79), Miller ('04, '05, '10), Dresbach ('11), and Johnson ('14) have each described one or more cases. In addition to the five described by Miller, three others have been observed by him. Professor Miller has kindly permitted me to make use of his notes of these three cases, two of which were mentioned, but without description, by Dresbach.

Miller's Case 6 was similar in all respects to that reported by him in 1904, which is redrawn in figure 2, D. Case 7 corresponded with the one reported in 1905, except that the pancreatic bladder was distinct and separate from the gall-bladder. Case 8 was similar to that described in 1910, redrawn in figure 2, C.

The example of pancreatic bladder observed by the writer is therefore the thirteenth to be placed on record. It is the ninth to be reported from this laboratory within a period of fifteen years. The remaining recorded instances are from so widely separated localities, one from Minneapolis, two from Ithaca, and one from Europe, that there appears small probability that inheritance is to be considered a factor in their formation.

The present case differs somewhat from those previously described, and for that reason may be of interest. It was observed in an approximately half-grown female cat. Inquiry as to the origin of the animal, aside from the fact that it was obtained in the city of Madison, proved fruitless.

The pancreatic bladder itself (fig. 1) occupied the same relative position with respect to the gall-bladder as the majority of those

previously noted. It was slightly larger than the gall-bladder and extended beyond the fundus of the latter for a distance of about 6 mm. It was connected by a main duct with the ductus pancreaticus, resembling in this respect the case described by Mayer. This main duct crossed the ductus choledochus before uniting with the ductus pancreaticus. It joined the latter about midway between the point of confluence of the two axial ducts

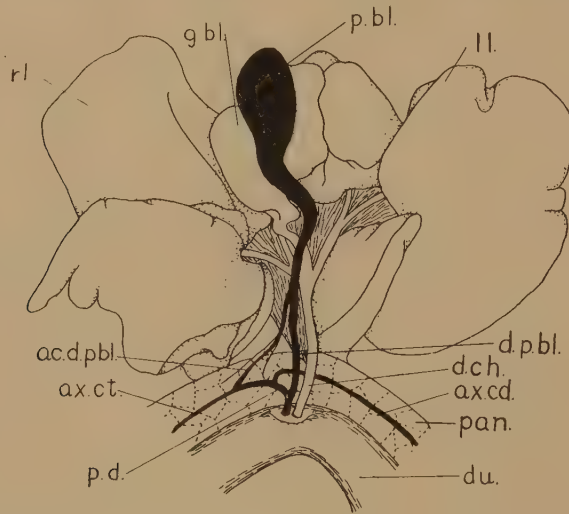


Fig. 1. Pancreatic bladder from half-grown cat. The liver has been turned forward. *ac. d. p. bl.*, accessory duct of pancreatic bladder; *ax. cd.*, axial duct of the tail of the pancreas; *ax. ct.*, axial duct of the head of the pancreas; *d. ch.*, ductus choledochus; *d. p. bl.*, duct of pancreatic bladder; *du.*, duodenum; *g. bl.*, gall-bladder; *l. l.*, left lobe of liver; *pan.*, pancreas; *p. bl.*, pancreatic bladder; *p. d.*, ductus pancreaticus; *p. t.*, pancreatic tissue; *r. l.*, right lobe of liver. About natural size.

and the ampulla of Vater. It was loosely attached to the ductus choledochus for part of its course by connective tissue, but the two ducts were easily separated from each other.

About 1 cm. from the point of union of the principal duct with the ductus pancreaticus, it gave off a branch of smaller diameter, which, however, was large enough to admit a fine bristle for a considerable distance. This branch duct entered the head of the pancreas and opened into the axial duct of the latter. A

thin wedge of pancreatic tissue extended out from the caput along this duct for a distance of 7 mm., resembling in this respect the instance described by Miller in 1910. On dissecting away the pancreatic tissue along the course of this small duct, the latter was observed to become reduced in diameter within the mass of the wedge, but enlarged again before uniting with the axial duct. The point of union with the latter was 3 mm. from the origin of the ductus pancreaticus.

The accessory pancreatic duct was not found, but it does not appear likely that any relation existed between it and the small duct described.

A comparison of figure 1 with the several diagrams of figure 2 will indicate that this smaller duct has a relation to the axial ducts of the pancreas similar to that shown by the single duct of the pancreatic bladder in the majority of cases described, i.e., it connects with the axial duct of the head of the pancreas.

In but two instances (Gage, '79, and Miller, '05) is there any connection of the pancreatic bladder with the duct of the tail of the pancreas. In two others (Dresbach, '11, and Johnson, '14) the duct of the pancreatic bladder opens into a sinus-like enlargement in common with the axial ducts. This sinus empties into the ampulla of Vater by the ductus pancreaticus, which in the case described by Dresbach can scarcely be said to be present.

Two other cases beside the one here described, show a duct direct from the pancreatic bladder to the ductus pancreaticus. As illustrated in Mayer's figure, schematized in figure 2, E, the duct from the bladder unites with the ductus pancreaticus to form a short tube which Mayer calls the 'ductussialodochus.' Gage describes the duct from the pancreatic bladder as dividing, the smaller division entering the ductus pancreaticus (fig. 2, F). It appears possible that the sinus-like enlargements observed by Dresbach (fig. 2, G) and by Johnson may have been formed by the union of the pancreatic cystic duct with the ductus pancreaticus very close to the point of origin of the latter within the substance of the pancreas. If this be so, five of the thirteen cases of pancreatic bladder have a duct which may be regarded as

opening into the ductus pancreaticus rather than into either of the axial ducts of the pancreas.

With respect to the origin of these anomalous structures, the suggestions advanced by Miller ('10) appear to be borne out in the present instance. According to Miller, pancreatic bladders are modifications of pancreatic ducts which are occasionally present in the cat (Heuer, '06).

They presumably originate either from one of the lobes of a bilobed rudiment of the ventral pancreas or possibly from one of the paired rudiments of the ventral pancreas. Helly ('01) finds the ventral pancreas sometimes paired in embryos of the cat and certain other mammals, and F. T. Lewis ('11) in a study of 150 pig embryos, found a left lobe of the ventral pancreas well developed in seventeen cases and rudimentary in seven others. He believes the pancreatic bladder, when present, to be developed from the left lobe of the ventral pancreas.

In figure 2, illustrations from several authors are somewhat schematized and arranged in the order of their degree of modification from the simplest (fig. 2, A) to the condition which appears to be most modified from the embryonic rudiment (fig. 2, G). The instance described in the present report would have its position, aside from the differences in its ducts, between C and D of figure 2, because of the wedge of pancreatic tissue described.

The larger duct in the present instance (fig. 1), which opens into the ductus pancreaticus, may have been formed secondarily by anastomosis of lobar ducts between the ductus pancreaticus and the duct of the particular rudiment of the ventral pancreas from which the pancreatic bladder was formed. Subsequently the duct thus formed became larger than the original primary duct, which remains as the small duct opening into the axial duct of the head of the pancreas. It appears likely that the two branches observed by Gage may also be accounted for on this hypothesis. In his case the original primary outlet of the pancreatic bladder retained its larger size, while the small duct which opens into the ductus pancreaticus would correspond with that which is the larger in figure 1. It is possible that the outlet of the pancreatic bladder in the instance described by Mayer

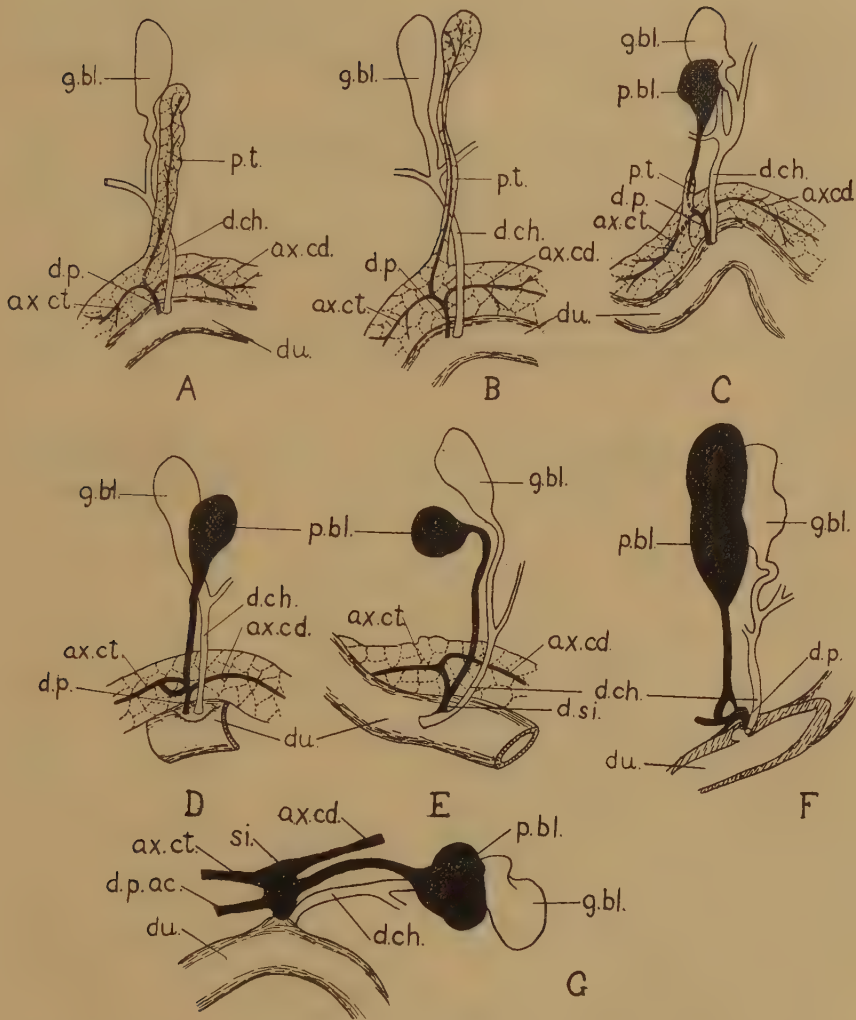


Fig. 2 The various figures are schematized to some extent from the drawings of the authors indicated, as follows:

A. From Miller, '10 (fig. 2).

B. From Miller, '10 (fig. 3).

C. From Miller, '10 (fig. 1).

D. From Miller, '04 (fig. 1).

E. From Mayer, 1815 (fig. 1). *d. si.*, ductus sialodochus.

F. From Gage, '79 (fig. 2).

G. From Dresbach, '11 (fig. 1). *d. p. ac.*, accessory pancreatic duct; *si.*, sinus. Lettering of all figures modified to conform with figure 1, and other abbreviations same as in figure 1.

into the ductus pancreaticus may be similarly accounted for, save in this case the original primary duct of the pancreatic outgrowth which gave rise to the bladder must be assumed to have entirely disappeared.

Another possibility is presented, namely, that the mass of pancreatic tissue from which the pancreatic bladder developed, contained several ducts connected with either the axial ducts or the ductus pancreaticus. All but one, or in some instances, two, of these ducts atrophied concomitantly with the modification or atrophy of the pancreatic tissue of the rudiment, leaving only the main ducts which were connected with the pancreatic bladder.

My acknowledgments are due Prof. W. S. Miller for reading the manuscript and for several suggestions which have been made use of.

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Resumen por el autor, A. W. Meyer.

El método de los casos clínicos y problemas en la Neurología
anatómica.

Puesto que el estudio de la complicada anatomía del sistema nervioso central por los estudiantes se reduce casi por completo a aprender de memoria, el autor indica que en la enseñanza de esta materia se debiera recurrir, con mucha mas frecuencia que hasta el presente, a la exposición de casos clínicos reales e hipotéticos. Tal procedimiento no solamente haría la tarea del estudiante menos complicada y mas interesante sino que también dirigiría su atención sobre la existencia de muchas relaciones oscuras. El objeto de este método no es restringir la atención del alumno a consideraciones prácticas, ni tampoco anticipar su trabajo clínico, sino el usar casos concretos con el propósito de revelar las relaciones complejas y fijarlas en la mente de un modo mas permanente. Este método está particularmente justificado en Neurología, porque el estudio objetivo del sistema nervioso central solo puede ser parcial aún cuando se lleve a cabo en las mejores condiciones.

Translation by José F. Nonidez
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THE CASE AND PROBLEM METHOD IN ANATOMIC NEUROLOGY

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Seers and prophets of old frequently taught by parable. This is essentially the interpretation of a particular set of circumstances by the case method. Revered teachers of medicine of the past also used hypothetic and actual cases to illustrate some general principle. A fitting illustration often can illumine what otherwise would remain obscure, and, because of its efficiency, objective teaching no doubt dates back far in human history. Although we of to-day do not claim to be either seers or prophets, we nevertheless have abundant opportunity to extend the applications of the case method in our teaching not only in anatomy, but in physiology and in psychology of the abnormal as well.

Among the various educational subjects, medicine particularly has had the distinction of long making free use of the living individual. This is true especially in clinical teaching, and a more extensive application of the case and problem method in the teaching of anatomy not only would seem possible, but highly commendable. It should be found especially advantageous for illustrating obscure structural relations, such as vascular anastomoses, sympathetic connections, and above all certain features in the anatomy of the central nervous system. Even with the best of equipment it long will remain difficult not only for the student to realize the existence of tracts, the extent of which he cannot demonstrate and which he can examine only here and there throughout their entire complicated course.

Anatomic neurology still remains such a bugbear to the student largely because of the nature of the things themselves. The structural relationships of the central nervous system are so intricate and an examination of them in continuity naturally

must remain impossible. Hence much must be left to imagination and memory, and many a physician will recall with what relief he, as a student, turned from the anatomic to physiologic and clinical neurology. This common experience justifies the emphasis recently placed by certain neurologists upon the so-called methods of functional neurology, for the association of structure and function, although often impossible, nevertheless makes a necessarily difficult task far less tedious and meaningless.

Under the exigencies of the situation, a long list of clinical cases selected from the literature not only would furnish a welcome relief to the student, but would teach him much regarding the structure and function of the nervous system. To select such a list admittedly would be a considerable task to anyone except a practicing neurologist of wide experience, but it would be worth while. Some good examples could be gleaned from text-books on clinical neurology, and medical literature is replete with material of this kind. Moreover, the literature of the great war has added many illustrations of the effects of lesions of the nervous mechanism. It no doubt would be very difficult to get a large series of clean-cut cases, but many of them could be used in part in order to illustrate some particular feature which it is desired to emphasize. This would save the student from confusion and postpone consideration of associated phenomena.

No one pretends to be sure that the whole anatomy of the nervous or any other system can thus be illustrated. Besides many symptoms or signs exhibited by these cases or case histories would be wholly inexplicable at present, but there would be a lesson and a stimulus in all this to both student and teacher, and the medical student later would approach the patient more understandingly than is otherwise likely. If one began with simple cases of peripheral injuries resulting in simple disturbances in function and followed these by a series of more proximal lesions and, finally, by a considerable group of cases illustrating the effects of lesions in various segments of the cord, medulla, and the rest of the brain, the student would be confronted with a most interesting series of problems and conditions, the interpretation of which not only would require clear thinking, but would

fix in his memory structural relations and physiologic conceptions which otherwise are easily forgotten or even overlooked.

Anyone who has ever tried the case method in anatomy knows with what delight it is hailed by the student. This is due not merely to its direct human appeal, but to the eloquence with which accident and disease often reveal obscure structural relationships. Next to a thorough examination of the structures themselves, I know of no better way to impress certain anatomic relations upon students than to consider the effects of displacements, pressures, and injuries upon them and adjacent organs. One cannot, for example, properly consider the effects of air or fluid in the pleura or pericardial cavities without emphasizing many anatomic facts and referring to interrelationships otherwise easily overlooked.

In suggesting the wider application of the case and problem method, especially in anatomic neurology, I am fully aware of the limitations imposed by both time and method. Nor would I rely solely upon this method, or even try to anticipate clinical neurology. That would be both futile and unwise, and although the collection of a large and excellent series of cases will require much time, I am certain that the histories of a select list of clinical cases can greatly enrich our anatomic instruction and add meaning and interest to purely morphologic considerations. The extent to which the method can be used is a matter of minor importance only.

Since physiologists have left the field of muscular movements to the anatomists, it would seem that the latter no longer should neglect this opportunity to use the case and problem method for the demonstration of muscular actions. Even the best of our text-books of systematic anatomy merely tabulate what has come to be regarded as the most obvious or conspicuous action of particular muscles, without giving the student any idea of the intricate relationships and the splendid coordination illustrated by muscular movements. Anatomists seldom consider muscular movements as such, and physiologists usually take up only certain special groups of movements, such as those of respiration, deglutition, coughing, sneezing, and sometimes a few

others, and with these considerations a very interesting and important subject is usually dismissed. I mention this not, to be sure, as an indictment or accusation, but merely to call attention to the situation.

Our text-books of systematic anatomy also assign actions to muscles which they undoubtedly do not perform, and a thoroughgoing discussion of muscular movements long has waited upon some anatomist with physiologic training and practical experience, or a physiologist with considerable anatomic knowledge and clinical interest. How incomplete our knowledge of muscular movements is, a neurologic patient occasionally illustrates to the student. At present there are but a few small volumes which consider muscular movements other than more or less incidentally. A thoroughgoing modern discussion of this subject would be a great boon to both the student and the anatomist. Let us hope that English neurologists who have contributed so much to the subject soon will answer this need.

In making these brief suggestions, I am aware of the fact that pedagogic reflections coming from a laboratory worker are regarded as time ill spent by many of us. Nor is this difficult to understand. Yet most of us spend a large part of our lives in formal teaching and only a few fortunate or exceptional individuals could retain their positions in public or quasi-public educational institutions on a purely investigational basis. Deny it though we may, we are where we are, and are doing what we are, because we are expected to teach, not merely by example, but by very word and deed. Hence it would seem that under these circumstances an intolerant attitude toward improvement and change in method is discreditable, whatever else it may not be. To spend a lifetime in a teaching position, and, in fact, to make a livelihood—such as it is—by teaching, and then entertain an inhospitable attitude toward considerations upon the methods by which that livelihood is made does justice to nothing save the inadequate and immutable salaries characteristic of institutions of higher education.

Resumen por el autor, Frank C. Mann.

Clínica Mayo, Rochester, Minn.

Estudio comparativo de la anatomía del esfínter del extremo duodenal del conducto biliar común, con especial mención del de las especies de animales desprovistas de vejiga biliar.

El autor ha hecho un estudio anatómico del esfínter situado en el extremo duodenal del conducto biliar común en diez especies de animales provistos de vejiga biliar y cuatro especies desprovistas de ella, encontrándose diferencias considerables en lo referente al trayecto del conducto a través de la pared del duodeno y a la disposición de las fibras musculares alrededor del conducto. Existe una disposición definida de las fibras musculares, que puede funcionar como un esfínter en cada una de las especies estudiadas; no se ha podido hallar diferencia alguna cuando se comparan los animales provistos de vejiga biliar con los que carecen de ella. No cabe duda que algunas especies de animales sin vejiga biliar poseen una disposición anatómica en forma de músculos dispuestos alrededor del extremo duodenal del conducto biliar, los cuales pueden funcionar como un esfínter.

Translation by José F. Nonidez
Carnegie Institution of Washington

A COMPARATIVE STUDY OF THE ANATOMY OF THE SPHINCTER AT THE DUODENAL END OF THE COM- MON BILE-DUCT WITH SPECIAL REFERENCE TO SPECIES OF ANIMALS WITHOUT A GALL-BLADDER

F. C. MANN

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FOUR FIGURES

In previous investigations^{4,5} it was emphasized that the removal of the gall-bladder was usually followed by dilatation of all the extrahepatic ducts. This dilatation did not take place if all the muscle fibers surrounding the common bile-duct in its passage through the duodenal wall were destroyed. Furthermore, in our experiments, the sphincter at the end of the common bile-duct was either not physiologically active or it was less active than in animals in which the gall-bladder had not been removed. Because of these facts, great importance is attached to the interrelation of the action of the gall-bladder and sphincter. Accordingly, it was believed that an anatomic difference might be found between the sphincter of animals with gall-bladders and those without them.

This sphincter has been studied anatomically by Gage, Oddi, and Hendrickson. It has been said that Glisson first suspected such a sphincter, but Gage seems to have been the first to describe the structure. In an extensive study of the ampulla of Vater and pancreatic ducts in the cat, he describes a sphincter around the common bile-duct and pancreatic duct and another sphincter common to both ducts.

Oddi made an extensive comparative investigation of the sphincter to which his name is usually attached. He studied the duodenal portion of the common bile-duct by maceration and histologically in man, the dog, sheep, ox, pig, cat, horse, domestic

pigeon, common fowl, and guinea-fowl. He found that the course of the duct through the duodenal wall differs in the various species of animals. The arrangement of the smooth muscle around the duct likewise differs. In each species studied, he was able to demonstrate, however, a definite sphincter at the duodenal end of the common bile-duct.

A most complete study of the musculature of the entire extra-hepatic biliary system, including that of the sphincter, was made by Hendrickson, in the dog and the rabbit and in man. Both by maceration and by the microscope, he was able to demonstrate a definite sphincter in each species.

According to the list of species reported by Oddi, the gall-bladder is absent in only a few, such as the horse and pigeon. In the horse the duct opening is quite patulous, and in the pigeon the duct system is complex. Since it seemed advisable to study the sphincter in other species without a gall-bladder, we obtained specimens from four such species—the horse, deer, rat, and pocket gopher (*G. bursarius*); the three latter had not been previously studied. As controls, we also studied the sphincter in the dog, cat, rabbit, guinea-pig, ox, goat, pig, sheep, striped gopher (*C. tridecemlineatus*), and mouse, which possess a gall-bladder.

The sphincter was studied macroscopically and microscopically; the latter method was found to be the more valuable because many of the specimens were very small. The specimen of the sphincter was secured immediately after the death of the animal and placed in the fixative, usually formalin. The specimen was subsequently trimmed to the smallest size that would give the complete course of the duct, and paraffin serial sections were made.

This study corroborates the observations of previous investigators with regard to the variability of the course of the duct through the duodenal wall in the various species of animals. In each species the course seems to differ slightly from that of other species. This difference seems to depend mainly on the direction of the duct in relation to the axis of the duodenum and the thick-

ness of the duodenal walls. The relation of the course of the duct to the course of the duodenum was difficult to determine. Angles of various degrees between the course of the duct and the direction of the long axis of the duodenum are noted in various species. In some species the two are almost parallel for a relatively long distance, but the duct gradually passes through the duodenal wall. In other species the duct seems to pierce the wall of the intestine almost at right angles, but of course it does not actually do so. In a few species the duct turns almost at a right angle to the direction of its course within the duodenal wall. The relative position of the duct to the duodenal wall seems to depend, in a great measure, on the latter. In some species the intramural portion of the duct is relatively short, particularly in some of the species in which the intestinal wall is thin. In other species the intramural portion of the duct is relatively long. This is due either to a prolongation of the portion of the duct in the muscle wall or, as is usually the case, to the extension of the duct in the submucosa for some distance. The opening of the duct through the mucosa also differs in the various species; in most it is no larger than a pen point, but in a few it is patulous. It should be noted that both the direction of the duct through the duodenal wall and the method of opening into the duodenum do not differ in species of animals without a gall-bladder, as a group, from species of animals possessing a gall-bladder.

The bile-duct in each species was found to be surrounded by a bundle of smooth muscle, contraction of which closes the lumen of the duct. The amount of muscle tissue and the arrangement of it differs considerably in the various species, depending probably on the difference in the thickness of the wall of the duodenum and the course of the duct. In many species it is rather difficult to find muscle fibers which encompass the duct exclusively, because they are so closely intermingled with the circular fibers of the intestine. As a matter of fact, in many specimens the muscle fibers which might act exclusively as a sphincter are very few. Sometimes there is only an accentuation of the muscle coat in the intramural portion of the duct which has extended

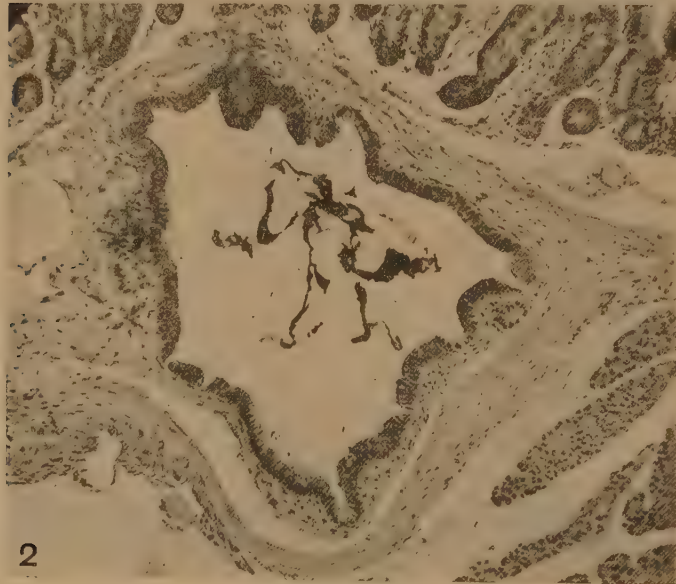
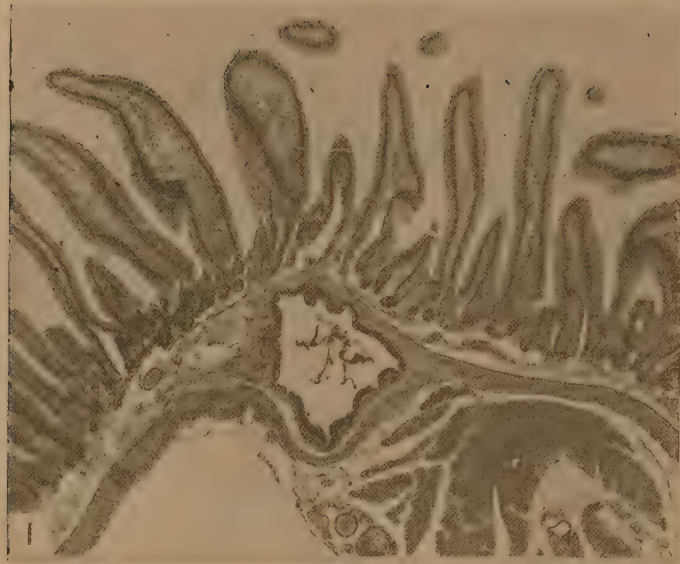


Fig. 1 Photomicrograph of section of hepatic duct of pocket gopher (*G. bursarius*) at about the middle of the course of the duct through the muscularis of the duodenum. The duodenal mucosa is at the top, a lobule of pancreas at the bottom to the right. Note how the muscularis surrounds the duct. $\times 40$.

Fig. 2 Photomicrograph showing a higher magnification of the same section shown in figure 1. Not only does the muscularis surround the duct, but there are a few fibers seemingly passed around the duct and interlacing with the muscle fibers of the muscularis. $\times 100$.

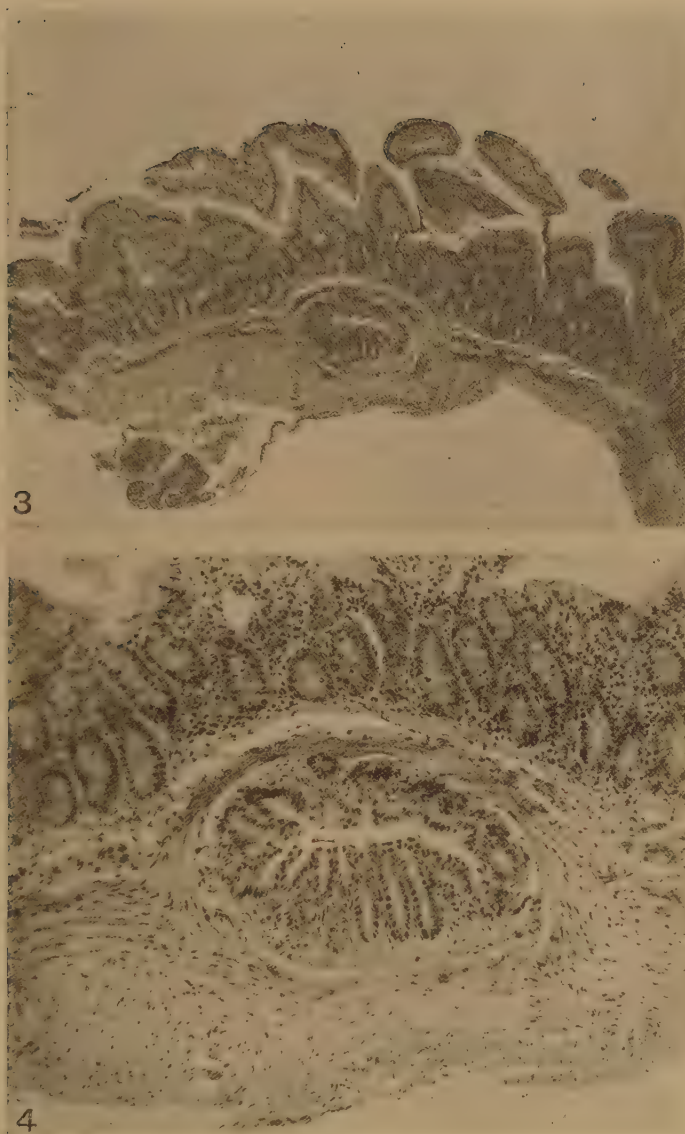


Fig. 3 Photomicrograph of section of hepatic duct of a rat, taken at the point where the duct passes into the submucosa of the duodenum. The duodenal mucosa is at the top, a lobule of pancreas below the muscularis to the left. $\times 40$.

Fig. 4 Photomicrograph of higher magnification of same section shown in figure 3. There is a relatively large bundle of muscle which completely surrounds the duct and interlaces with the muscularis of the duodenum. The sphincter is comparably as well developed in the rat as any species studied. $\times 100$.

from the extramural portion. When the arrangement of the circular muscle fibers of the intestine is considered in connection with the fibers which undoubtedly surround the duct, it is justifiable to conclude that a definite sphincter exists in each species studied.

No constant difference was observed in the histology of the sphincter in animals with a gall-bladder as compared with those without one, and no specific anatomic difference was found between the sphincters in the two groups of animals.

SUMMARY

An anatomic study was made of the sphincter of the duodenal end of the common bile-duct in ten species of animals with gall-bladders and four species without. Considerable difference was found with regard to the course of the duct through the duodenal wall and in the arrangement of the muscle fibers around the duct. There is a definite arrangement of muscle fibers which might functionate as a sphincter in each species studied; no difference could be observed in animals that have a gall-bladder when compared with those without one. There is no doubt that anatomically some species of animals lacking a gall-bladder have an arrangement of muscle around the duodenal end of the bile-duct which can act as a sphincter.

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Resumen por el autor, Edmond Souchon.

Escuela Médica Tulane, New Orleans.

Una nueva solución permanente para la conservación de preparaciones anatómicas: la solución Souchon de cloruro cálcico.

Esta solución se compone de 3 onzas de cloruro cálcico granular puro U. S. P. que se añade a un galón de agua filtrada. Se agita la mezcla hasta disolución del cloruro y se filtra antes de usarla. Añádase 5 onzas de formol transparente a cada galón de la solución para impedir el enturbiamiento del líquido a consecuencia del desarrollo de bacterias y moho en la superficie. Si este último aparece aun a pesar de haberse añadido formol, debe separarse, agregando dos o tres cucharadas de pedacitos de timol o alcanfor. El símbolo de esta excelente solución es C3.F5. Es mejor que cualquier otro de los fluidos empleados hasta el presente y les supera en eficacia, simplicidad de composición y baratura. Las preparaciones no le comunican color alguno. La solución no necesita cambiarse, como sucede con otras mezclas; una misma solución sirve para siempre. Solamente se necesita filtrarla una o dos veces para evitar su enturbiamiento, mientras que otras soluciones necesitan filtrarse varias veces. Antes de filtrar los filtros deben mojarse con agua filtrada, que después de pasar a través del filtro debe resultar completamente límpida. Si aún a pesar de la filtración la solución no resulta transparente, añádase medio dracma de sulfato alumínico pulverizado, agítese la mezcla y fíltrese. Esta solución sustituye a la mezcla de alcohol y glicerina, que es mucho mas cara. La descripción del método Souchon para la conservación de disecciones anatómicas se ha publicado en el *Anatomical Record*, Marzo 1917.

A NEW PERMANENT SOLUTION FOR THE PRESERVATION OF ANATOMIC PREPARATIONS, THE SOUCHON SOLUTION OF CALCIUM CHLORIDE

EDMOND SOUCHON

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The solution is composed of 3 ounces of pure granulated calcium chloride U. S. P. to 1 gallon of filtered water. Stir to dissolve and filter before using.

Add 5 ounces of clear white formol to each gallon of solution, to prevent cloudiness from bacterial development and mildewing at the top. Should mildew occur anyhow, remove the mildew and sprinkle the surface of the solution with two or three tablespoonfuls of tiny lumps of thymol or camphor. Camphor is much cheaper. C3.F5 is the symbol of this solution.

It is an ideal solution. It excels anything of its kind ever used before in efficiency, simplicity of composition, and cheapness. Preparations will not discolor it. The solution does not need to be changed as other solutions have to be, one solution will do for all time. It requires one or two filtrations for cloudiness, whereas other solutions require four or five or more. Before filtering the solution, filtered water must be run through the filters. The water must come out clear before filtering the solutions. Should some solution not filter clearly, add $\frac{1}{2}$ drachm of pulverized aluminum sulphate, stir and filter over.

The solution is quite cheap, about fourteen cents per gallon—four cents for the calcium and ten cents for the formol. When the old prices of calcium and formol return, the cost will be about ten cents per gallon of solution. This solution takes the place of the ultra-expensive alcohol and glycerine.

The description of the Souchon methods of preservation of anatomic dissections is described in the *Anatomical Record* published by The Wistar Institute of Anatomy of Philadelphia, November, 1915, and March, 1917.

The chemical method described in the November, 1915, number has been abandoned as being inferior to the newer curing method, described in the March, 1917, number.

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Resumen por la autora, C. J. Beckwith.
Colegio Vassar, Poughkeepsie, N. Y.

Nota sobre una vejiga pancreática anómala en el gato.

En una disección de un gato se encontró una vejiga pancreática. Su conducto se abría en el conducto pancreático principal. El ejemplar descrito difiere de otros casos en la presencia de una rama comunicante entre el conducto de la vejiga pancreática y el conducto cístico, cerrado por encima de este nuevo conducto comunicante. Esta particularidad aisla la vejiga biliar del conducto cístico, transformando a este último en un órgano no funcional. La vejiga pancreática aparentemente asume la función de la vejiga biliar, pasando a ella la bilis desde el conducto cístico a lo largo de la rama comunicante.

Translation by José F. Nonidez
Carnegie Institution of Washington

NOTE ON A PECULIAR PANCREATIC BLADDER IN THE CAT

CORA JIPSON BECKWITH

Vassar College

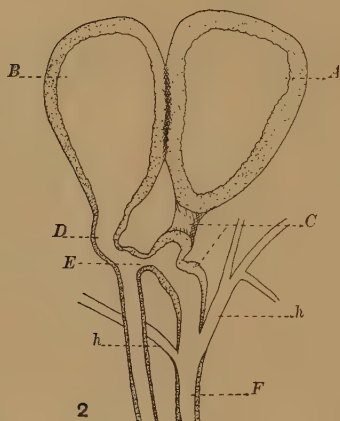
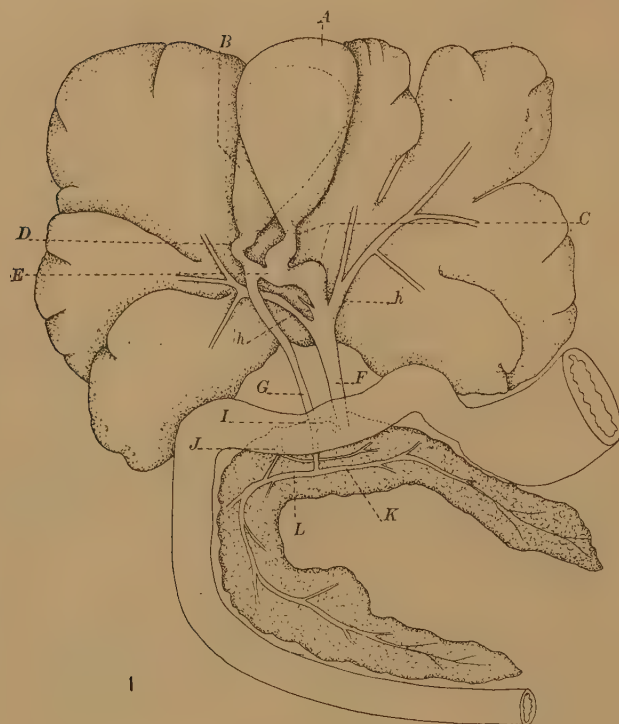
TWO FIGURES

The presence of a pancreatic bladder lying in the liver beside the gall-bladder has been reported in a few cases in the cat. The case here presented differs from these sufficiently to make a note of it desirable. A brief review of the condition in those forms which I have found recorded will be necessary for comparison. These all belong to one general type with slight modification of the ducts.

Mayer, in 1815, describes the appearance of a pancreatic bladder lying on the right side of the gall-bladder. Its duct which lay parallel to the ductus choledochus (common bile-duct) opened into the duct of Wirsung or main pancreatic duct just before it entered the duodenum. The pancreatic bladder is smaller than the gall-bladder.

In 1879, Gage records a similar case in which the pancreatic bladder lies at the right side of the gall-bladder and is larger than the latter. The two bladders are very closely bound together by connective tissue, but there is no communication between the two. The duct from the pancreatic bladder leads to the pancreatic duct, into which it opens by two ducts of unequal size, a small one into the duct of Wirsung (main pancreatic duct) and a large one into the gastrosplenic branch of the duct.

No further case was recorded until 1904, when Miller describes three cases in cats which were obtained from the same farm house or a neighboring one. Two of his cases are similar. The gall-bladder occupies its normal position, while the pancreatic bladder which is smaller is bound to the free surface of the gall-bladder. In the third case the pancreatic bladder which is



larger occupied the position of the gall-bladder, the latter lying on the right side of the pancreatic bladder, the two being bound together by connective tissue. In all three cases the duct from the pancreatic bladder opened into the duodorsal division of the pancreatic duct—a point in which they differ from the preceding cases.

The case which has come under my observation is that of a preserved cat dissected by a student in the Vassar College laboratory. Its origin is not known. It differs in a number of points from the above cases. The pancreatic bladder, which is smaller than the gall-bladder, lies behind it, partially covered by it (fig. 1). They are bound together along the apposing sides by connective tissue. The duct from the pancreatic bladder lies parallel to the ductus choledochus (common bile-duct) and opens into the duct of Wirsung after the union of the two divisions (duodorsal and gastrosplenic) of the pancreatic duct. The striking thing about this case is a cross-connecting branch between the duct from the pancreatic bladder and the cystic duct. It lies less than a centimeter from the origin of the ducts from their respective bladders. The cystic duct is swollen above and below the point of union with this cross duct, while it is constricted between this bulged portion and the gall-bladder. Dissection of the ducts revealed the fact that the lumen of the duct from the gall-bladder (cystic duct) at the point of constriction, i.e., between the gall-bladder and the communicating branch was closed by connective tissue (fig. 2). The mucous

Fig. 1. Ventral view of the liver and bladders. *A*, gall-bladder; *B*, pancreatic bladder; *C*, cystic duct (closed above communicating branch); *D*, duct from pancreatic bladder; *E*, connecting branch between the cystic duct and the duct from the pancreatic bladder; *F*, ductus communis choledochus (common bile-duct); *G*, duct from pancreatic bladder just before opening into the pancreatic duct; *h*, ductus hepatici (hepatic ducts); *I*, duct of Wirsung-ductus pancreaticus (main pancreatic duct); *J*, duct of Santorini (accessory pancreatic duct); *K*, gastrosplenic branch of the pancreatic duct; *L*, duodorsal branch of the pancreatic duct.

Fig. 2. Diagram to show the cavities of the bladders and the lumen of the ducts. Lettering as in figure 1.

lining of the gall-bladder was not continued into this portion. The lining of the cystic duct was slightly thickened in the swollen portions and became continuous with the lining of the duct from the pancreas through the cross connection. This necessitates the flow of bile for storage from the cystic duct through the cross connection into the pancreatic bladder. The flow of bile from the pancreatic bladder to the duodenum has two paths open to it—one through the upper end of the duct from the pancreatic bladder through the cross branch, thence through the cystic duct and common bile duct; the other through the duct from the pancreatic bladder directly to the duct of Wirsung (main pancreatic duct) into the duodenum.

Careful investigation revealed no communication between the two bladders. Unfortunately, both bladders had been opened before I saw the specimen. The student reported the presence of a brownish fluid in both bladders. This means little, since the cat had been preserved in an alcohol-formalin-glycerin mixture for several months. A striking thing is that the mucous lining of the gall-bladder is much thicker than the lining of the functioning pancreatic bladder. So far as sections reveal the structure, there is no essential difference in the mucous lining of the two bladders.

Two possibilities suggest themselves as to the origin of this condition. Miller and Heuer suggest that the pancreatic bladder may have arisen out of a condition described by both of them. They each cite two cats in which an accessory lobe of pancreatic tissue follows the ductus choledochus (common bile-duct) to the gall-bladder. In one of the cases described by Miller the pancreatic tissue extends nearly to the gall-bladder. It contains a duct which joined the duodorsal division of the pancreatic duct. In the second specimen a duct arising from the duodorsal branch of the pancreatic duct and which was bare of pancreatic tissue ran parallel to the ductus choledochus and ended in a lobe of pancreatic tissue which lay in the fossa of the gall-bladder. Heuer's cats correspond in general to Miller's first case, except that the duct present in the accessory lobe of pancreatic tissue joined the gastrosplenic branch of the pancreatic duct. Both

writers suggest the origin of a pancreatic bladder and duct by the loss of the pancreatic tissue in this lobe, leaving the duct lying parallel to the ductus choledochus, while the free end expands into a bladder. In the case which I have described a new connection between the duct from the pancreatic bladder and the cystic duct would have, then, to be formed as a new development. The large size of the gall-bladder and its thick walls together with the swollen condition of the duct suggest that such a communication was formed after the blockage of the cystic duct near its origin from the gall-bladder.

The other alternative which occurs to one is based on another condition described by Miller in a cat that was a brother to one of the pancreatic-bladder cases already described. In this form there were two gall-bladders present, one occupied the usual position, the two hepatic ducts from the left lobes of the liver joined its cystic duct. Beyond this point a duct from the right lobes joined the cystic duct to form the common bile-duct. The duct from the median right lobe beyond the point where it branched from that of the right lateral lobe expanded to form the second, smaller gall-bladder lying at the right of the typical gall-bladder. If a duct from an accessory pancreatic lobe such as Miller described joined the duct of this secondary gall-bladder, the condition which I have described and figured would be formed. This supposition seems less favorable to the writer than the one first described, since this one does not account for the blockage of the original cystic duct or the swollen condition of that duct below the stoppage. At most, these suggestions are guesses, accurate knowledge of the origin of such a condition can only rest on the embryology of the pancreas and liver.

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Resumen por el autor, R. L. Draper.

El crecimiento prenatal del conejillo de indias.

El conejillo de indias es muy susceptible a la acción del frío y a los cambios bruscos de temperatura y dieta. Estos agentes son frecuentemente la causa de la muerte de los individuos adultos y también de abortos. La temperatura mas conveniente para estos animales es la de 60° a 70° F. El periodo de celo no puede determinarse fácilmente mediante la observación externa, durando cinco horas en un caso extremo. La fecundidad del conejillo de indias se ha exagerado. Solamente un cuarenta por ciento de las hembras criadas quedaron preñadas. Los embriones de menos de diez y siete dias no pudieron pesarse satisfactoriamente. Las variaciones de peso de los embriones jóvenes son relativamente mayores que las de los fetos pertenecientes a los estados ulteriores de la gestación. El crecimiento es rápido desde el décimo-quinto dia hasta el vigésimo-quinto día de la gestación. Decece rápidamente al principio y después mas despacio durante el resto del periodo. El embrión no aumenta en longitud con la misma intensidad con que aumenta de peso desde el décimo-quinto hasta los sesenta y cuatro dias. El fluido amniótico y las membranas mantienen, relativamente, la misma relación con el crecimiento del embrión, aumentando mas rápidamente al principio y después mas despacio desde los veinte y nueve, y treinta y dos dias, respectivamente.

Translation by José F. Nonidez
Carnegie Institution of Washington

THE PRENATAL GROWTH OF THE GUINEA-PIG

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FIVE CHARTS

In the beginning of these experiments the animals were kept under outdoor conditions similar to those to which they were accustomed. They were sheltered from the wind, but not from the cold or changes in weather, and fed on alfalfa. Diarrhoea, which generally ended in death, followed and those that were pregnant aborted. Convulsions were noted in a few cases, followed soon by death and abortion. A number of others aborted without any apparent cause.

At necropsy the intestinal tract appeared to be normal in some, while in others the intestines were inflamed and distended with gas. Fresh green vegetables were then substituted for some of the dry feed and the animals protected from the cold. The sick ones immediately recovered and no further abortions occurred. Hence cold was probably the cause of the trouble, although the guinea-pig is very susceptible to changes in diet and seems to succumb to the slightest disorders of the intestinal tract. However, abortions occurred also later.

Lantz ('13) also found that susceptibility to disease is closely related to the quality and quantity of food eaten. Improper, irregular, and deficient feeding is common cause of inflammation of the stomach and bowels, from which losses among the animals may be very great. In my experience the guinea-pig does best when it is kept at a temperature of from 50° to 70°F. However, Lantz found that the guinea-pig does best when the temperature is not allowed to fall below 65°F. The pig survives a chill very badly and recovers very slowly. It is upset by irregular feedings

and must have plenty to eat. When they are well fed they stand the cold fairly well, but nevertheless do poorly. Sudden changes of temperature have an ill effect. I have found that the young also are very sensitive to cold, for they died when the temperature dropped from 60° to 58°F. Pregnant females almost always aborted when chilled even when digestive disturbances were absent. Too much food, on several occasions, also seemed to be a cause for abortions.

It may be of some interest to record that the pig may go for a long period of time without water if given plenty of green stuff, and nevertheless do very well. I have let them go for six months without any water except what was obtained from green food, such as lettuce, carrots, cabbage, etc.

In order to keep track of the age of the embryo, the female, after copulation, was placed in a cage by herself or with one pregnant pig that was easily distinguishable. Every step to eliminate any source of error was taken. The cage was tagged, giving a description of the pig and the hour and date of copulation. The pigs were never changed from one cage to another.

On an appointed day the pig was weighed and then killed with illuminating gas. The uterus was exposed and severed from its connections, using care to free the uterine wall of any excess of surrounding tissue. The oviducts were cut across at the junction with the uterus (a point easily recognized by a slight constriction at the point of junction). The uterus was then separated from the vagina and the vaginal wall removed. The weight of the uterus was then taken before it was opened, and the embryos removed in a definite order. The ova were more easily removed when the uterine wall was incised over the placental site, which was readily recognized by an area lighter than the surrounding uterine tissue and by its firmness. The very small ova were easily detached from the uterine wall by means of a camel-hair brush, weighed and opened and the embryos removed. The cord was cut about 3 mm. from its fetal attachment after being tied to prevent the loss of a varying amount of blood. The superfluous fluid was removed with blotting-paper and the

embryos weighed on a chemical balance as soon as taken from the membranes to prevent any considerable loss in weight by evaporation. An attempt was made to treat the embryos as nearly alike as possible to prevent errors in loss of weight.

A watch crystal of known weight was used as a receptacle and thoroughly dried and cleaned before and after each weighing. The embryos too large to be weighed on a chemical balance were weighed on a torsion balance accurate to 0.1 gram.

The length was taken with a caliper, a number of readings being taken of each specimen and the average used, to exclude as much error as possible. All the measurements and weighings were carefully checked and tabulated at once and embryos and placentae preserved in 10 per cent formalin and labeled as to weight and age.

It is recognized that there is a constant error in weighing such small objects by the loss of unequal amounts of fluid or by unequal amounts of fluid clinging to the surface. The smaller the embryo the relatively greater will the error be. In measuring the length of young embryos a source of error lies in the changes in posture and in the delicacy of the tissue. Hence it is advisable to harden the embryos in formalin before taking measurements. This method likewise is subject to criticism because formalin swells young tissue, but in embryos during the latter part of gestation this source of error would be considerably less.

The observations taken of the weights and lengths were recorded after the following form:

Number of pig	Weight of foetus and unopened
Date of coitus	membranes beginning dis-
Date of death	tally in the right and left
Weight of pig	horn
Weight of uterus and contents	Weight of membranes and fluid
Weight of empty uterus	Weight of membranes alone
No. of foetuses	Weight of foetus alone
Right	Length of foetus
Left	

Obviously, the only accurate method of obtaining data of the prenatal growth of the guinea-pig is to weigh the embryo. Read

('13) obtained his observations on the prenatal growth by estimating the weight of the guinea-pig embryo from weights of the mother on succeeding days. This method is obviously inaccurate for, as Minot ('91) pointed out, the digestive tract with a particularly wide caecum always contains a considerable amount of ingested food, the bladder containing a greater or less amount of urine, and sickness all introduce great fluctuations. Another source of error is the difficulty of controlling the act of defecation and urination before each weighing. Since the early embryo weighs but a few milligrams, while other things may and do cause a variation in grams, the value of Read's method in determining the weight of the embryo is at once evident.

In obtaining the data for this paper, the age of the embryo was calculated from the day of copulation, and the female killed a definite number of days following, although this does not necessarily assume that conception follows within twenty-four hours after copulation. Von Hansen ('76), in studying the descent of the ovum, also made use of copulation in age determination and found that ovulation takes place from six and one-half to nine and one-half hours following coitus. Minot ('91) observed that when copulation took place in rut the fertilization took place within twenty-four hours. It would seem then that it is safe to assume that conception follows within twenty-four hours after copulation and that the latter age less one day lies within a reasonable error of the true age of the embryo.

In calculating the ages of the embryos it became necessary to know when the females became pregnant. Assuming that the ovum was impregnated within a comparatively short time after copulation, it became necessary to know when coitus took place in order to determine the age of the embryo. Hence the female was tried each night and morning, by putting the male in the same cage for a short period of time. The male approached the female promptly and if she was in heat coitus followed at once. If not, she never would submit later, but kicked the male and uttered complaining noises. Occasionally a female was noted to assume the manner of a male, uttering a purring sound and

walking about the cage in a strutting manner, but I saw a female attempting to mount another female when in heat only on a few occasions. The female does not always object to being mounted by the male, but will not assume a position necessary for copulation unless in heat. Others resist vigorously at first, but submit to mounting if the male persists. Such submission was only noted a few times, however.

If in rut the female will react when stroked lightly over the hips, by assuming the position for copulation. This confirms Loeb and Lathrop ('14), who found that in "Animals kept under normal conditions the period of heat occurs approximately every fifteen to nineteen days. When females are kept together in a large pen, some will be seen sitting quiet, some eating a little or walking about, making a small sociable, clucking noise. If one moves occasionally, rather majestically among the rest, making a low, purring noise similar to the noise of the male, she is probably in heat; if not, she soon will be. In some cases a female guinea-pig may reach a state of excitement in which she assumes the manners of a male and attempts copulation with another pig which happens to be in heat. She as well as the second guinea-pig that allows her to attempt the rôle of the male, will almost always be found ready for copulation. When one or very few females are kept in a small cage and have become relatively tame, those in heat when tickled along the flanks and hips will react to the touch of the finger, assuming the position for copulation. This sign, however, is of no value when the animals are timid."

It occurred to me that it might be of some value to know how long a female stayed in heat, and five hours was the longest duration observed. Some refused the male in three hours. One objected in twenty minutes after copulation. Just how long she was in heat before copulation was not determined however, but it was less than fifteen hours in any case.¹ A vigorous male

¹ After the compilation of the data here presented, which were obtained in 1915-16, I learned that Stockard and Papanicolaou ('17) concluded that heat in the guinea-pig lasts about twenty-four hours and that the external appearances of the vulva are not absolutely reliable. George, in unpublished observations,

will copulate many times in a few minutes, but he becomes exhausted after a number of acts and will not mount again for some time, even if put in with a fresh female. Since the male is generally not very active for twelve hours following copulation, three males were kept and used on alternate days only.

The guinea-pig was found to breed in greater numbers during the spring months from February to June. The greater number of copulations took place in April and the greater number of pregnancies also quite naturally took place during this month. During the autumn months the greater number of copulations occurred in November, but the total number of animals bred was only 98. Of this number 48 were killed and found pregnant. Four of the 98 aborted. Five of the pregnancies were bloody moles, and 41 pigs failed to become pregnant. That is, in 40 per cent of the number in which copulation occurred, the pigs failed to become pregnant. Hence, it would seem that the fecundity of the guinea-pig is not as great as is generally supposed. This confirms the statement of Lantz ('13) that the fecundity of the guinea-pig has been greatly exaggerated.² The guinea has but two mammae and her period of gestation varies from sixty-three to seventy days. A female in her breeding prime may be expected to raise about twelve to fifteen young each year.

It is of some interest to note that of 145 embryos obtained from 48 pigs, 76 were found in the left horn and 69 in the right. The average number of foetuses per pregnancy was practically 3. Five embryos were the greatest number found in a pregnant uterus and two the least. Minot ('11) noted that the number of young was 1 to 8 in a litter, 1, 2, 3, and 4 occurring most frequently. The most frequent combination in my series was

came to the conclusion, however, that careful inspection of the vulva was sufficient in thirty cases observed by him, and that since twelve out of thirty-six pigs did not mate in thirty-four days, although females were tried twice diurnally, the oestrus cycle must often be longer than sixteen days or the period of heat less than twenty-four hours. George felt inclined to the latter conclusion, because among other things several pigs mated after more than sixteen days.

² A large series of cases would seem to be required for reliable conclusions regarding this matter, for out of a series of thirty pigs, George found only one that failed to become pregnant upon the first mating.

two embryos in one horn and one in the other. Two were found in one horn about as frequently as in the other. Pregnancy occurred nine times in one horn alone. In pregnancies where there was a single embryo in one horn and two or more in the other, the single embryo was found to weigh more than the other embryos in 80 per cent of the cases.

The embryo in a ten-day ovum still was so small that it was impossible to open the membranes and isolate the embryonic disc from them even with the aid of a lens under water. The measurements of the three ova of this age were 6.5 mm. x 3 mm.; 6.8 mm. x 4.5 mm., and 6.5 mm. x 4.5 mm. Two eleven-day ova were removed from the uterus and weighed. One ovum was opened and something which was taken to be the embryo was recovered. This, with about an equal amount of gelatinous material, was weighed. The embryo appeared to be 2 mm. long. The membranes of a fourteen-day ovum were also opened in water under a dissecting microscope, and a white streak, apparently the embryo, seen; but an attempt to isolate it, failed. It was closely associated with a very delicate amnion, and the estimated length was 2.5 mm. A fifteen-day ovum was isolated with difficulty and the weight of the embryo estimated to be only about 1.5 mgm.; but an ovum of seventeen days was of sufficient size, so that the embryo could be isolated with considerable care. Since they lie in fluid, the error in weighing such small embryos is necessarily very great, considering that a drop of water weighs 50 mgm.

If the data so obtained are accurate and sufficient in number for each day, then any point on the curve plotted from the data obtained should represent the median weight of the embryo for that age. For instance, an embryo of forty days weighs 10 grams, according to the curve, and this corresponds to the actual weighings. The curve shown on chart 1 conveys the impression that the embryo grows faster during the later part of pregnancy; but this, of course, is not true, for a curve plotted from the weights and ages of the embryos represents only the relation of the weight to age and of the weights to each other or the actual increase

in growth from day to day, but not the rate of growth which is indicated on chart 2.

From this chart it is obvious that it is impossible to represent graphically on a chart the weight of the early embryos for the reason that the increase in weight per day is so small in relation

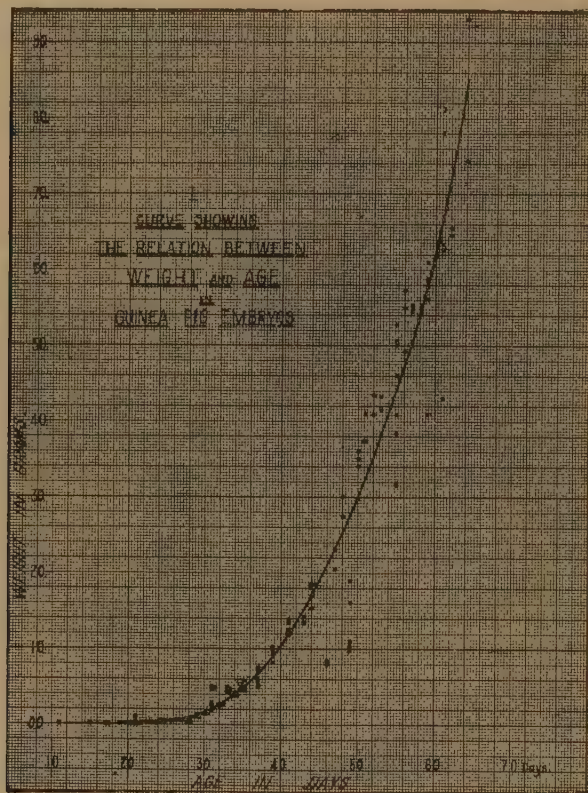


Chart 1 shows the relation of the age to the weight in the guinea-pig embryo computed from table 1. Age in days is represented on the abscissa, 2.5 mm. representing one day, and weight of the embryo is given in grams on the ordinate, 2.5 mm. representing 1 gram. Each dot represents the actual weight of the embryo.

to the age. The circles representing the weights fall nearly on a straight line until the twenty-eighth day is reached, when there is a gradual rise. This is explained by the fact that the weight

of the embryo from day to day is not great enough in relation to the age and our means of measurements to produce a rise in the curve. The overlapping of the circles in the first part of the curve is clearly due to the extremely small weights. The variation between the weights of the very early embryos is relatively greater than that of the older ones. This is partly

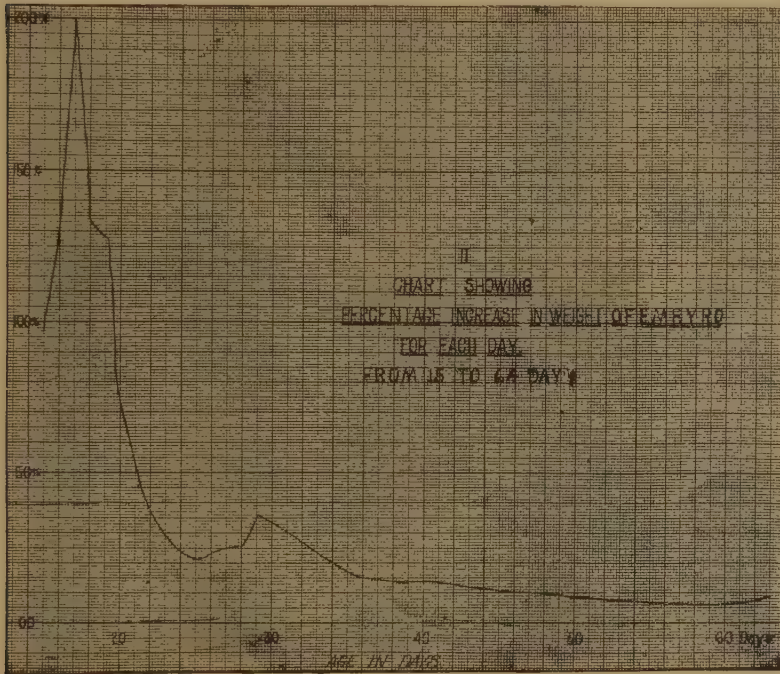


Chart 2 shows a curve representing the percentage increase in weights per day. Age in days is given on the abscissa, 5 mm. representing one day, percentage increase on the ordinate, 1 mm. representing 1 per cent. The curve is computed from data in table 2.

due to the fact that there is more chance for error in weighing small specimens, although some of the embryos in the same litter varied as much as 100 mgm. This is not apparent from the chart. The weights falling far outside the curve may be explained by the variation in the growth or by some error in obser-

vation. The percentage daily increase in growth represents the actual rate at which an embryo grows from one twenty-four-hour period to the next; for the weight at the beginning of a twenty-four-hour period subtracted from that at the end of the period is the increase in the twenty-four hours, or the daily increment, and from this the rate of growth can be computed. The curve of the daily percentage increase in weight, chart 2, shows a tre-

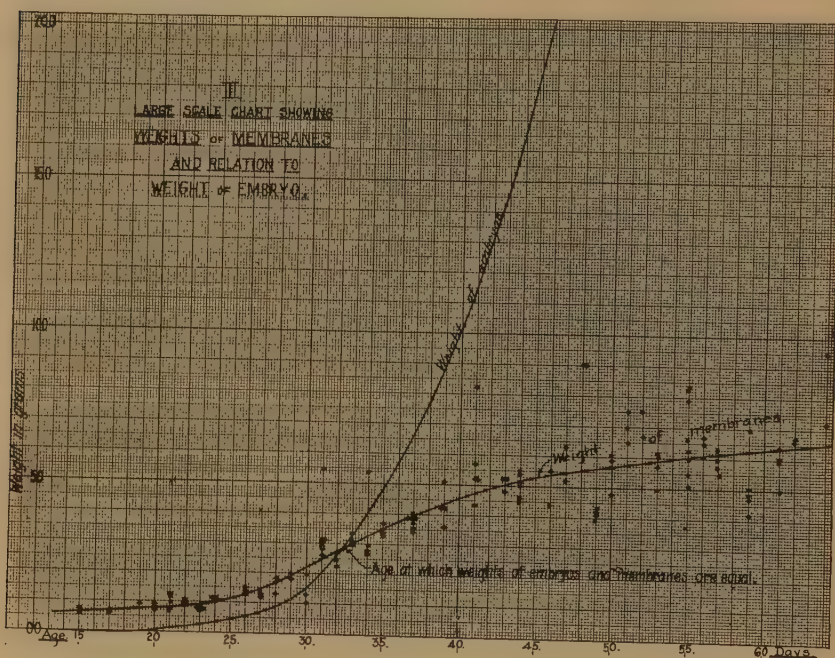


Chart 3 shows the relation between the weight of the embryo and the weight of the membranes. Weight in grams on the ordinate, 10 mm. equaling 1 gram, age in days on the abscissa, 2.5 mm. equaling one day. Weight of the membranes taken from table 1. Each individual weight represented by a circle.

mendous increase in the rate of growth in the early stages of development as compared to the curve showing the increase in weight. At the end of the seventeenth day the daily percentage increase is 200 per cent, but by the twentieth day it drops to 20 per cent. This is followed by a rise to 35 per cent, and then there is a gradual decline to 10 per cent at the end of the sixty-fourth day. It is evident that the rate of growth would gradually

decrease, and the curve would reach the base line when the guinea-pig reached its full growth following birth. Just how to explain the first rise in chart 2 is not clear. The curve begins with 100 per cent on the fifteenth day and rises to 200 per cent on the seventeenth day; but this is not what one would expect.

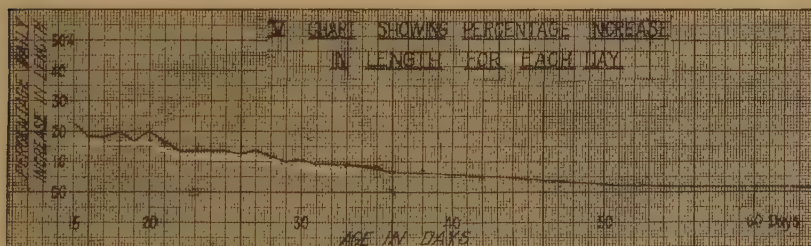
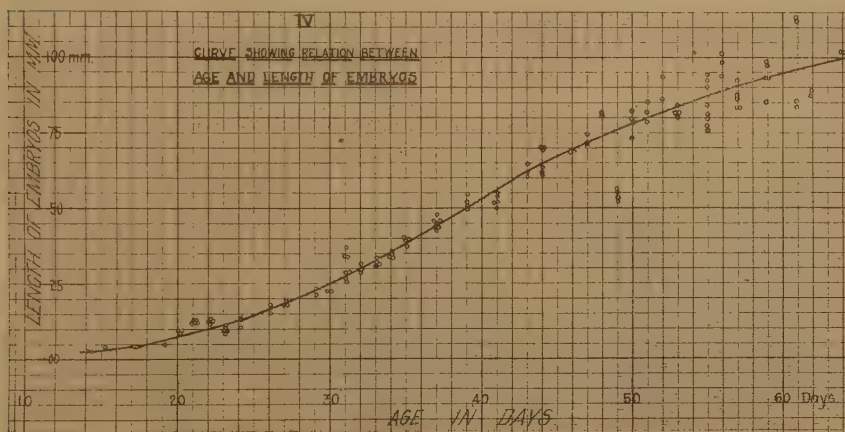


Chart 4 shows the relation between the age and the length of the embryo. Length in millimeters is given on the ordinate and age in days on the abscissa, 5 mm. equaling one day. The data were taken from table 1, each circle representing the actual length of the embryo. This curve represents the actual increase in the length of the embryo, the individual lengths being represented by circles.

Chart 5 shows the daily percentage increase in length computed from the data in table 3. The daily percentage increase in length is given on the ordinate, 1 mm. equaling 1 per cent and age in days on the abscissae, 5 mm. equaling one day.

It may be due to the very few weights or to errors of observation since we are dealing with such small weights.

The curve of the percentage increase in length, chart 5, is a smoother curve than that of the percentage increase in weight; the daily percentage increase being more uniform. It would seem that the embryo in its early stages of growth does not increase in length at the same rate as it does in weight. The daily increase in length on the seventeenth day is only 18 as compared to 200 per cent in the daily percentage increase in weight. It begins at a daily increase of 23 per cent on the fifteenth day, and follows a gradual decrease to 1 per cent on the sixty-fourth day.

In comparing the relation between the membranes and the embryos of corresponding ages shown on chart 3, it will be noted that during the first month the weight of the membranes is greater than that of the embryos. (The term 'membranes' is used here to include the placenta and the membranes.) Between the thirty-second and thirty-third days they are equal, and after that the embryos gain rapidly in weight, while the membranes gain slowly. Between the twenty-fifth and the forty-fourth day the curve shows a more rapid increase in the growth of the membranes than following this time. Probably this period of rapid increase is an expression of nutritional demand on the part of the embryo. The growth of the membranes is not in proportion to the increase in weight of the embryo, for when they have reached sufficient size to meet the demand of the embryo, there is no further need for their rapid continued growth. From this chart it would appear that the greater difference occurs among the individual weights during the latter part of gestation. This may be accounted for by the larger individual weights and the large scale of the chart. The table shows that the same variation occurs throughout the term of growth. It is probable that the size of the placenta may exert some influence upon the rate of growth of the embryo. The smaller placenta necessarily furnishes less surface for nutritional interchange on account of its small uterine attachment.

The average amount of amniotic fluid taken from each ovum, as tabulated in table 1, shows that it holds the same relation

to the embryo as does the membranes, and is greater than the weight of the embryo up to the twenty-ninth day. From the twenty-ninth to the thirty-second day it equals the weight of the embryo, after which it increases slowly to the forty-fourth day and remains about the same for the rest of the gestation period. The amount of fluid and the weight of the membranes are equal on the thirty-fifth day and remain approximately the same to the sixty-fourth day.

CONCLUSIONS

The guinea-pig is very susceptible to cold and to sudden changes in temperature and diet. These things frequently are the cause for the losses among the pigs and for abortions.

A temperature ranging from 60° to 70°F. was found the most suitable.

Rut was found difficult to determine by external observations only and five hours the longest period of heat noted.

The fecundity of the guinea has been exaggerated. Only 40 per cent of the number bred became pregnant.

Embryos under seventeen days could not be weighed satisfactorily.

Variations between the weights of early embryos are relatively greater than those from the later part of gestation.

Growth occurs rapidly from the fifteenth to the twenty-fifth day. It decreases rapidly at first and then more slowly for the rest of the period.

The embryo does not increase in length at the same rate as it does in weight from the fifteenth to the sixty-fourth day.

The amniotic fluid and the membranes maintain, relatively, the same relation to the growth of the embryo, increasing more rapidly at first and then more slowly after the twenty-ninth and thirty-second days, respectively.

It is a special pleasure to thank Professor Meyer for suggesting and outlining the subject for investigation, for his continued interest, and for revision of the manuscript.

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TABLE 1

Gives the age of the embryos and the observations tabulated in the order taken. The individual weights and lengths of the embryos and the membranes are listed in the order of their removal from the uterus. The number of weights after the age represents the total number of embryos at this age. From this table the curve of the median averages for weight and length are plotted. The small weights obtained for the ages of thirty-two and forty-six days probably are errors in observation or due to a mistake as to the day of copulation

AGE IN DAYS	WEIGHT OF UTERUS AND CONTENTS	WEIGHT OF UTERUS	NUMBER OF OVA	COMBINED WEIGHT OF MEMBRANES AND CONTENTS
10	1.560	1.229	3	0.154
11	2.307	1.773	3	0.425
14	2.809	1.675	2	0.992
15	2.868	1.260	2	1.467
17	3.763	1.805	2	1.830
19	3.903	2.410	0	
20	5.923	1.623	4	3.950
21	4.613	1.762	3	4.513
	9.350	2.000	2	3.360
22	10.553	2.448	5	7.517
23	10.843	2.874	5	6.911
24		2.660	0	7.831
26	11.675	2.878	3	7.821
27	11.435	1.318	3	7.803
28	9.620	3.230	2	4.090
29	12.010	2.670	2	8.770
30	15.593	4.443	3	10.183
31	47.450	7.090	3	19.966
	37.830	4.390	4	38.500
32	26.038	4.455	3	20.939
33		6.450	3	26.950
34	42.883	4.585	4	36.710
35	53.403	6.883	4	44.223
37	71.900	10.360	4	56.610
37	51.400	7.966	3	38.389
39	78.983	8.740	4	69.733
41	56.290	10.600	2	44.340
	74.500	7.400	3	62.800
43	83.200	8.700	3	71.990
44	97.220	10.700	3	85.000
	97.220	12.810	3	81.700
46	63.400	7.000	1	27.500
47	111.700	7.200	3	102.900
48	95.000	8.500	2	87.500
49	80.530	6.770	4	73.632
50	201.500	11.122	4	186.511

TABLE 1—*Continued*

AGE IN DAYS	WEIGHT OF UTERUS AND CONTENTS	WEIGHT OF UTERUS	NUMBER OF OVA	COMBINED WEIGHT OF MEMBRANES AND CONTENTS
51	161.500	13.500	3	147.000
52	119.040	11.950	2	106.110
53		17.100	0	
55	194.500	12.800	4	179.100
	279.100	17.600	3	189.905
56	213.330	18.370	0	
57			5	302.000
59	153.500	6.800	2	138.950
59	190.750	12.220	3	177.450
61	140.600	11.200	2	124.900
	200.900	15.650	2	189.000
62	158.950	9.550	2	148.800
64	205.700	12.000	2	203.000

AGE IN DAYS	WEIGHT OF INDIVIDUAL					Average weight of ova in grams
	Ova in grams					
10	0.066	0.007		0.0810		0.074
11	0.1416	0.140		0.1442		0.141
14	0.506	0.386				0.446
15	0.779	0.688				0.723
17	0.957	0.873				0.915
19						0.000
20	1.418	1.285		1.690		1.464
21	1.589	1.264		1.660		1.543
	1.990	1.370				
22	1.800	1.920		2.045	1.732	1.879
23	1.383	1.473		1.308	1.364	
					1.383	1.362
24						
26	2.310	2.653		2.858		2.607
27	3.008	2.558		2.235		2.600
28	1.310	2.780				2.050
29	4.780	3.990				4.380
30	3.895	1.760		4.528		3.394
31	7.482	6.484		6.000		6.655
	9.920	10.200		10.740	7.640	9.620
32	7.208	6.603		7.128		6.979
33	8.450	9.550		8.950		8.732
34	8.982	9.225		8.855	9.648	9.188
35	11.1630	11.560		10.7200		
				10.7800		11.050

TABLE 1—*Continued*

AGE IN DAYS	WEIGHT OF INDIVIDUAL						Average weight of ova in grams
	Ova in grams						
37	13.650	14.980		13.7900			14.220
	12.153	13.103		14.4900			12.796
39	17.235	15.465		13.1330			
				17.9080			17.433
41	25.520	18.820		19.1250			
	21.400	19.400		22.0000			21.530
43	23.000	24.200		22.0000			23.630
44	27.500	27.000		24.7000			28.330
	25.490	28.540		35.0000			27.900
46		27.500		29.6700			27.500
47	33.700	35.200		34.000			34.300
48	45.000	42.500					43.750
49	19.078	18.513		17.753			
				18.288			18.650
50	47.808	45.973		46.253			
				46.478			46.629
51	48.000	50.500		48.500			49.000
52	52.390	53.720					53.050
53							
55	47.600	41.700		39.000	50.800		44.520
		66.800		53.640	64.465		64.930
56							
57	60.000	55.000	61.00	62.000	64.000		58.400
59	74.500	64.450					68.470
	64.350	66.950	46.15				59.150
61	50.800	74.100					62.450
	87.900	86.200					87.000
62	73.300	75.500					74.400
64	95.000	108.000					101.500

AGE IN DAYS	WEIGHT OF EMBRYOS						NUMBER OF EMBRYOS	AVERAGE WEIGHT IN GRAMS
11	0.0018						1	
14							0	
15	0.0015						1	
17	0.005	0.006					2	0.005
19	0.035						1	0.035
20	0.109	0.105	0.087				3	0.100
21	0.131	0.148	0.110	0.1240	0.127		5	0.177
22	0.217	0.252	0.210	0.225			4	0.223
23	0.178	0.265	0.233	0.209	0.234		5	0.224
24	0.299	0.432	0.412				3	0.381

TABLE 1—*Continued*

AGE IN DAYS	WEIGHT OF EMBRYOS					NUMBER OF EMBRYOS	AVERAGE WEIGHT IN GRAMS
26	0.493	0.543	0.665			3	0.567
27	0.673	0.573	0.754			3	0.666
28	0.210	0.710	0.390			3	0.436
29	1.290	1.075				2	1.182
30	1.427	0.117	1.450			3	1.438
31	2.463	1.940	2.160			3	2.187
31	4.660	4.920	4.890	2.970		4	4.820
32	2.693	2.590	2.760			3	2.640
33	5.000	4.450	4.350	4.500		4	4.575
34	3.819	3.835	3.697	4.010		4	3.848
35	4.568	4.668	4.593	4.638		4	4.616
37	7.010	7.360	6.840			3	7.040
37	5.253	6.023	5.943			3	5.740
39	9.343	8.250	9.908	10.052		4	9.388
41	12.000	12.400	12.000	13.490	13.870	5	12.906
43	13.400	13.800	14.000			3	13.733
44	18.000	18.700	18.500			3	18.400
44	15.490	17.070	18.520			3	17.360
46	8.000	8.200				1	8.100
47	20.070	23.200				2	21.950
48	31.000	27.700				2	29.350
49	11.160	10.190	9.931	10.260		4	10.385
50	36.058	29.903	34.048	35.150		4	33.790
51	37.000	41.000	37.500			3	38.500
52	40.800	43.480				2	42.950
53	41.800	41.600	43.400	38.400		4	41.300
55	38.400	31.970	31.900	40.900		4	37.090
55	50.580	52.700	46.140	50.300		4	50.000
56	57.420	49.370	55.020			3	55.900
57	54.000	49.000	54.000	54.000	55.000	5	53.000
59	60.950	56.050				2	58.500
59	57.800	58.770	40.950			3	52.500
61	81.620	78.100				2	79.860
61	43.000	62.600				2	52.800
62	64.500	65.500				2	65.000
64	74.500	93.200				2	83.850

AGE IN DAYS	LENGTH OF EMBRYOS IN MILLIMETERS					NUMBER OF EMBRYOS	AVERAGE LENGTH IN MILLIMETERS
11							
14							
15							
17	4.250	4.250				2	4.250
19	5.000					1	5.000

TABLE 1—Continued

AGE IN DAYS	LENGTH OF EMBRYOS IN MILLIMETERS					NUMBER OF EMBRYOS	AVERAGE LENGTH IN MILLI- METERS
20	9.250	9.250	9.000			3	9.166
21	12.000	12.000	12.500	12.000	12.200	5	12.100
22	12.250	13.000	12.250	12.000		4	12.375
23	9.700	9.500	10.000	9.200	10.200	5	9.700
24	14.500	10.050	13.000			3	12.600
26	15.200	17.000	17.500			3	16.500
27	18.500	18.000	18.000			3	18.100
28	00.000					0	
29	21.500	23.500				2	22.500
30	22.700	22.750				2	22.300
31	29.500	26.000	27.000			3	27.500
31	37.000	34.000	34.000	29.500		4	33.600
32	32.000	29.000	30.000			3	30.300
33	31.500	32.500	34.000	32.000		4	32.500
34	34.000	35.000	34.000	36.000		4	34.700
35	40.000	40.050	39.700	40.050		4	40.100
37	48.000	46.000	44.000	46.000		4	46.000
37	43.000	45.500	44.000			3	44.100
39	52.500	50.000	51.000	55.000		4	51.700
41	51.500	52.500	52.500	54.500	55.000	5	53.400
43	65.000	62.600	61.500			3	63.000
44	70.500	70.000	70.000			3	70.300
44	61.500	63.000	64.000			3	62.800
46	69.500	69.500				2	69.500
47	75.000	72.500	71.000			3	72.800
48	84.500	82.000				2	83.200
49	57.000	56.000	54.000	53.000		4	55.000
50	74.000	79.000	74.000	83.000	80.000	4	79.000
51	82.500	79.500	86.000			3	82.500
52	87.000	94.000				2	90.500
53	82.500	82.200	80.500	85.000		4	82.500
55	80.000	78.000	80.500	76.500		4	79.800
55	91.000	93.000	85.000	95.000		4	91.000
56	102.000	99.000	94.500			3	98.500
57	87.000	84.000	93.000	84.000	88.000	5	87.200
59	94.000	94.000				2	94.000
59	98.000	99.000	86.000			3	94.300
61	114.000	113.000				2	113.700
61	86.500	84.500				2	85.500
62	65.000	88.000	90.000			2	89.000
64	83.850	102.500	102.500			2	102.500

TABLE 1—*Concluded*

AGE IN DAYS	WEIGHTS OF MEMBRANES ADNEXA					NUMBER OF OBSERVA- TIONS	AVERAGE WEIGHT OF MEM- BRANES AND ADNEXA	AVERAGE WEIGHT OF AMNIOTIC FLUID IN GRAMS PER OVUM
15	0.718	0.569				2		
17	0.657	0.590				2	0.633	
19	0.910					1	0.910	
20	0.985	0.690	0.738			3	0.804	0.560
21	0.739	0.697	1.260	1.150	0.985	5	0.924	0.445
22	0.935	0.890	1.040	0.935		4	0.947	0.704
23	0.780	0.773	0.715	0.750	0.800	5	0.763	0.373
24	1.112	1.042	1.123			3	1.092	0.000
26	1.332	1.451	1.542			3	1.435	0.605
27	1.438	1.328	1.283			3	1.346	0.598
28	1.380	1.785	1.740			3	1.100	0.516
29	2.060	1.795				2	1.977	1.121
30	1.280	1.067	1.945			3	1.430	0.326
31	3.013	2.830	2.660			3	2.814	0.654
31	3.120	3.150	5.420	2.870		4	3.560	1.204
32	2.768	2.253	2.435			3	2.485	1.854
33	3.950	4.350	4.100	4.000		4	4.100	0.057
34	2.668	5.390	2.733	2.933		4	3.428	1.920
35	3.493	3.710	3.343	3.359		4	3.430	3.004
37	3.450	3.930	3.580	3.790		4	3.690	3.490
37	3.963	3.953	4.013			3	3.976	3.080
39	4.283	3.345	4.225	5.095		4	4.312	3.700
41	5.200	5.700	5.200	8.240	4.340	5	5.810	2.814
43	5.200	4.800	5.200			3	5.060	4.837
44	4.500	5.000	5.500			2	5.000	4.930
44	4.510	5.130	5.410			3	5.010	5.540
46	5.500	4.400				2	4.900	14.000
47	5.200	6.300				2	5.750	6.600
48	9.000	9.000				2	9.000	5.400
49	4.293	4.128	3.970	4.220		4	4.150	4.115
50	6.020	5.998	5.748	4.858		4	5.656	7.183
51	6.500	7.000	7.560			3	7.000	4.500
52	6.770	7.510				2	7.140	2.040
53	6.000	5.670	6.110	4.930		4	5.877	0.000
55	5.500	5.970	5.100	6.500		4	5.790	1.640
55	7.690	8.230	6.230	8.320		4	7.830	7.100
56	6.970	6.490	6.050			3	6.500	0.000
57	5.500	5.700	6.000	6.300		5	5.600	0.000
59	4.700	4.800				2	4.750	5.270
59	5.050	6.980	4.220			3	5.280	1.370
61	5.000	5.920				2	6.200	4.190
61	6.000	6.400				2	5.460	9.400
62	6.600	6.700				2	6.650	2.750
64	7.200	9.550				2	8.350	9.300

TABLE 2

Shows the median weight, the daily increase and the percentage increase per day.

The average weight for each day from the fifteenth to the sixty-fourth day was ascertained (column 11) from the curve (chart 1). The daily increase was next computed by subtracting the weight on one day from that twenty-four hours later (column 11). The percentage increase per day is the relation between the daily increase and the weight at the beginning of the twenty-four-hour interval

AGE IN DAYS	AVERAGE WEIGHT IN GRAMS	DAILY INCREASE IN GRAMS	PERCENTAGE DAILY INCREASE IN WEIGHT
15	0.0015		
16	0.0022	0.0007	47.00
17	0.0050	0.0028	127.00
18	0.0150	0.0100	200.00
19	0.0350	0.0200	133.00
20	0.0800	0.0450	128.50
21	0.1400	0.0600	75.00
22	0.2150	0.0750	53.50
23	0.2950	0.0800	37.20
24	0.3800	0.0850	28.80
25	0.4700	0.0900	23.70
26	0.5700	0.1000	21.30
27	0.7000	0.1300	22.80
28	0.8800	0.1800	25.70
29	1.1000	0.2200	25.00
30	1.5000	0.4000	36.40
31	2.0000	0.5000	33.30
32	2.6000	0.6000	30.00
33	3.3000	0.7000	26.90
34	4.0800	0.7500	23.60
35	4.9000	0.8200	20.05
36	5.7500	0.8500	17.35
37	6.6500	0.9000	15.65
38	7.6500	1.0000	15.05
39	8.8000	1.1500	15.05
40	10.1000	1.3000	14.76
41	11.5000	1.4000	13.85
42	13.1000	1.6000	13.90
43	14.8000	1.7000	13.00
44	16.6000	1.8000	12.15
45	18.5000	1.9000	11.45
46	20.5000	2.0000	10.80
47	22.7000	2.2000	10.72
48	25.0000	2.3000	10.14
49	27.4000	2.4000	9.06

TABLE 2—*Continued*

AGE IN DAYS	AVERAGE WEIGHT IN GRAMS	DAILY INCREASE IN GRAMS	PERCENTAGE DAILY INCREASE IN WEIGHT
50	29.9000	2.5000	9.13
51	32.5000	2.6000	8.70
52	35.2000	2.7000	8.31
53	39.0000	2.8000	7.95
54	40.0000	2.9000	7.64
55	43.9000	3.0000	7.33
56	47.1000	3.2000	7.25
57	50.4000	3.3000	7.02
58	53.9000	3.5000	6.94
59	57.6000	3.7000	6.86
60	61.6000	4.0000	6.94
61	66.0000	4.4000	7.10
62	71.0000	5.0000	7.60
63	77.0000	6.0000	8.50
64	84.0000	7.0000	9.10

TABLE 3

Shows the average length in millimeters, actual increase in length per day and the percentage increase in length. The average length for each day from the fourteenth to the sixty-fourth day was ascertained from the median curve on length (chart 4). The daily increase in length and the percentage increase were computed in the same manner as the daily increase and the percentage increase in table 2

AGE IN DAYS	AVERAGE LENGTH IN MILLIMETERS	ACTUAL INCREASE IN LENGTH IN MILLIMETERS PER DAY	PERCENTAGE DAILY INCREASE IN LENGTH
14	2.6		
15	3.2	0.6	23.0
16	3.8	0.6	18.7
17	4.5	0.7	18.1
18	5.4	0.9	20.0
19	6.4	1.0	17.1
20	7.7	1.3	20.3
21	8.9	1.2	15.5
22	10.1	1.2	13.5
23	11.5	1.4	13.8
24	13.0	1.5	13.9
25	14.8	1.8	13.9
26	16.7	1.9	12.8
27	18.8	2.2	13.1
28	21.0	2.1	11.1
29	23.0	2.0	9.5
30	25.5	2.5	10.9
31	28.1	2.5	9.8
32	30.0	2.2	7.7
33	33.0	2.8	9.3
34	36.0	3.0	8.8
35	39.0	3.0	8.3
36	41.7	2.7	6.8
37	44.3	2.6	6.2
38	47.5	3.2	7.2
39	50.4	2.9	6.1
40	53.3	2.9	5.7
41	56.3	3.0	5.6
42	59.0	2.7	4.7
43	62.0	3.0	5.0
44	65.0	3.0	4.6
45	67.5	2.5	3.8
46	69.8	2.3	3.5
47	72.2	2.4	3.4
48	74.5	2.3	3.3
49	76.7	2.2	2.9
50	78.8	2.1	2.7

TABLE 3—*Continued*

AGE IN DAYS	AVERAGE LENGTH IN MILLIMETERS	ACTUAL INCREASE IN LENGTH IN MILLIMETERS PER DAY	PERCENTAGE DAILY INCREASE IN LENGTH
51	80.9	2.1	2.6
52	82.5	1.6	1.9
53	84.2	1.7	2.0
54	86.0	1.8	2.1
55	87.8	1.8	2.0
56	89.3	1.5	1.7
57	90.7	1.4	1.5
58	92.2	1.4	1.5
59	93.5	1.3	1.4
60	94.9	1.4	1.5
61	96.5	1.6	1.6
62	97.7	1.3	1.3
63	99.0	1.3	1.2
64	100.0	1.0	1.0

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